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1.—A census of Pteridophyta of Western Australia

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Abstract

Forty-nine species of pteridophyta, including representatives of the Lycopsida, Psilopsida and Pteropsida, are listed for Western Australia. Their distribution within the State is given, as well as brief ecological notes on their habitats.

Introduction

Forty-nine species of ferns and fern allies are now known from Western Australia. They occur over a wide range of climate, from the tropics of the Kimberley and North-West Divisions to the temperate South-West Division and the arid interior of the State.

Plant collectors of the nineteenth and early present centuries collected most of these species during their investigations of the western land flora, but even so, our present knowledge of the distribution of most of them is somewhat fragmentary.

The ferns of the Kimberley are known mainly from the collections of W. V. Fitzgerald made in 1905 and 1906 (Fitzgerald 1916) and those of C. A. Gardner made in 1921 (Gardner 1923) and subsequent years. Other contributions to our meagre knowledge of these ferns were made by Allan Cunningham, Bradshaw and Allan, von Mueller, F. M. House and a few other collectors attached to expeditions of exploration into tropical Western Australia (Gardner 1923; Maiden 1917).

From extra-tropical Western Australia, many records of pteridophytes were obtained when large collections of the land flora were made by Preiss (Lehmann 1846-47), Drummond, Mueller, Oldfield and Diels. Several resident amateur naturalists of the 1800's also contributed to the distribution records of vascular plants, the more ardent collectors, being W. Webb, G. Maxwell, Miss J. Sewell and Miss S. J. Brooks.

Bentham's systematic treatment of the pteridophyta in Flora Australiensis in 1878 brought together, for the first time, the scattered records of Australian ferns. Bentham was able to record only 21 of the 49 species of Western ferns and fern allies, these being mostly the south-western ones. Few of the Kimberley ferns were known at that time.

Mueller (1882) enumerated the Australian ferns in his first census of Australian plants, but as this listing was partly an abstraction from Flora Australiensis it added nothing to the record for our western pteridophytes. Mueller's second census (Mueller 1889) likewise added nothing to the western fern record. Apart from Mueller's census of the ferns of extra-tropical Western Australia in the Western Australian Year Book for 1864-65 (Mueller 1896) and Andrew's short paper on ferns of the Perth district (Andrews 1902), there were no further publications on the group until 1930 when Gardner listed the pteridophytes in his census of vascular plants of Western Australia (Gardner 1930).

Western Australia still lacks a comprehensive, systematic treatment of its pteridophytes. There is only an illustrated key to ferns in Blackall (1954) by which the south-western pteridophytes may be keyed out. Therefore it is timely to present a census of our fern flora in terms of contemporary nomenclature and classification and to include the distribution records known to date.

Ecology

The western pteridophytes comprise a group of some 24 species of essentially tropical species and a group of some 25 extra-tropical species. The tropical group inhabits the Kimberley Division and part of the coastal portion of the North-West Division, or what Gardner (1942) has termed collectively the Northern Province. All these species occur elsewhere in northern Australia and in the Tropics of the Old World.

The group of extra-tropical species occurs in the southern temperate and arid parts of the State, or South-West Province and Eremean Province respectively, of Gardner (1942).

Fitzgerald (1916) and Gardner (1923) have shown that the fern flora of the Kimberley Division is a poor one for its geographically tropical position because of the scarcity of shade and the prevailing dry conditions between the months of May and October. The Northern Province has a summer rainfall and winter drought, the four consecutive wettest months being December to March or January to April.

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This seasonal pattern is obvious from the rainfall data given by the Bureau of Meteorology, Melbourne (1956) in the meteorological summary, "Climatic Averages Australia". In Table 1 an analysis of the average monthly rainfall data taken from this summary is presented for selected weather stations in Western Australia. The data for five stations in the Kimberley Division show the "wet season" to occur consistently from December to March inclusive (the four consecutive wettest months in the year). The periods, June to September or July to October are the four consecutive driest months of the year. In terms of annual rainfall Port George IV (Kunmunya Mission) has a yearly average rainfall of 50.39 inches. Wyndham 25.15 inches, Derby 23.96 inches, Broome 22.87 inches and Halls Creek 18.72 inches.

The summer rainfall pattern of the Kimberley extends over the northern part of the North-West Division where the total rainfall is considerably less than that of the Kimberley (see Table 1).

The Kimberley ferns are mostly restricted to the river forest formation of luxuriant vegetation bordering water-courses of the large valleys and gorges dissecting that rugged land. Within this formation are found *Adiantum philippense*, *Blechnum orientale*, *Ceratopteris thalictroides*, *Cyclosorus gongylodes*, *Dicranopteris linearis*, *Helminthostachys zeylanica*, *Lindsaea ensifolia*, *Lycopodium cernuum*, *Lygodium microphyllum*, *Microsorium scolopendria*, and *Stenochlaena palustris*. *Acrostichum speciosum* inhabits brackish swamps.

The few species which prefer more sunny and drier situations outside the river forest formation are *Platyzoma microphyllum*, *Cheilanthes vellea* and the ubiquitous *Cheilanthes tenuifolia*. The aquatic, *Ceratopteris thalictroides* inhabits water-courses in the Kimberley whilst some species of *Marsilea* are perhaps common in seasonally wet spots throughout the Northern Province and extending into the Eremean Province.

The few species of the tropical group which extend south of the Northern Province are found in small isolated stands in wet and shaded oases in otherwise temperate or arid country. *Psilotum nudum* has recently been collected from a gorge on the Murchison River in the South-West Province. Previous to this collection the only record of this plant in Western Australia, was Fitzgerald's collection from the Kimberley. *Pteris vittata* and *Cyclosorus gongylodes* both occur at Murchison River and again in the lower part of the South-West Province, showing extreme southerly extensions of their tropical distribution range.

The extra-tropical fern group is an impoverished part of the temperate fern flora of southern Australia. None of the species of this group is endemic in this State. Whereas Victoria has some 105 species of fern and fern allies, South Australia some 44 species, southern Western Australia has only 25 species, all of which occur elsewhere in southern Australia.

This fern flora is best developed in the sclerophyll forest formations of the extreme south-west. The South-West Province has a

TABLE 1

Distribution of winter and summer rainfall in Western Australia

Stations	Total Average Rainfall (inches): Four consecutive wettest months		Four consecutive driest months		Four remaining months	Year
Kimberley Division—						
Port George IV (Kunmunya Mission)	(Dec.-Mar.)	43·91	(Jul.-Oct.)	0·79	5·69	50·39
Wyndham	(Dec.-Mar.)	22·23	(Jun.-Sep.)	0·35	2·57	25·15
Derby	(Dec.-Mar.)	21·02	(Jul.-Oct.)	0·43	2·51	23·96
Broome	(Dec.-Mar.)	19·97	(Jul.-Oct.)	0·35	2·55	22·87
Halls Creek	(Dec.-Mar.)	15·45	(Jun.-Sep.)	0·64	2·63	18·72
North-West Division—						
Nullagine	(Dec.-Mar.)	9·45	(Jul.-Oct.)	0·76	2·77	12·98
Marble Bar	(Dec.-Mar.)	8·84	(Jul.-Oct.)	0·72	2·77	12·33
Port Hedland	(Jan.-Apr.)	7·95	(Sep.-Dec.)	0·50	2·56	11·01
Mundiwindi	(Dec.-Mar.)	6·89	(Jul.-Oct.)	1·10	2·59	10·58
Peak Hill	(Jan.-Apr.)	4·97	(Aug.-Nov.)	1·01	3·35	9·33
Winning Pool	(Jan.-Apr.)	5·06	(Sep.-Dec.)	0·45	3·39	8·90
South-West Division—						
Karridale	(May-Aug.)	31·42	(Dec.-Mar.)	4·22	11·98	47·63
Kalamunda	(May-Aug.)	29·50	(Nov.-Feb.)	2·86	10·45	42·81
Manjimup	(May-Aug.)	26·67	(Dec.-Mar.)	3·92	11·98	42·57
Collie	(May-Aug.)	26·09	(Dec.-Mar.)	3·04	10·47	39·60
Perth	(May-Aug.)	25·55	(Nov.-Feb.)	2·12	8·32	35·99
Mount Barker	(May-Aug.)	15·70	(Dec.-Mar.)	4·71	9·82	30·23
Walebing	(May-Aug.)	13·24	(Nov.-Feb.)	1·89	5·07	20·20
Katanning	(May-Aug.)	11·26	(Nov.-Feb.)	2·52	5·65	19·43
Morawa	(May-Aug.)	8·06	(Oct.-Jan.)	2·15	3·74	13·95
Kellerberrin	(May-Aug.)	7·94	(Nov.-Feb.)	2·07	3·88	13·89
Eastern and Eucla Divisions—						
Eucla	(Apr.-Jul.)	4·29	(Nov.-Feb.)	2·40	3·28	9·97
Wiluna	(Jan.-Apr.)	5·44	(Aug.-Nov.)	1·11	3·23	9·80
Menzies	(Mar.-Jun.)	4·23	(Aug.-Nov.)	1·92	3·17	9·32
Sandstone	(Mar.-Jun.)	4·00	(Sep.-Dec.)	1·60	3·51	9·11
Balladonia	(May-Aug.)	3·33	(Nov.-Feb.)	2·59	3·03	8·95
Laverton	(Dec.-Mar.)	3·96	(Jul.-Oct.)	1·58	3·13	8·67
Rawlinna	(Mar.-Jun.)	2·59	(Jul.-Oct.)	1·89	2·15	6·63

winter rainfall and summer drought. From Table 1 it will be seen that there is a marked winter rainfall from May to August inclusive (the four consecutive wettest months of the year). The four consecutive driest months are November to February or December to March. The average annual isohyet of 50 inches encloses a small area between Pemberton and Nornalup in the extreme south and occasional outliers along the Darling Scarp. The annual rainfall decreases northwards (Karridale 47.63 inches, Perth 35.99 inches, Walebing 20.20 inches, Morowa 13.95 inches) and eastwards (Karridale 47.63 inches, Manjimup 42.57 inches, Mount Barker 30.23 inches, Katanning 19.43 inches, Kellerberrin 13.89 inches). Consequent upon this climatic pattern there is a progressive decrease eastwards and northwards of the sclerophyll forest and the fern flora.

The woodland ferns of the sclerophyll forest formation of the Karri and Jarrah forests include *Pteridium esculentum*, *Lindsaea linearis* and *Adiantum aethiopicum*. Amongst outcrops of igneous rocks or metasediments are found *Anogramma leptophylla*, *Asplenium flabellifolium*, *A. adiantoides*, *Cheilanthes tenuifolia*, *Ch. distans*, *Ch. lasiophylla* and *Pleurosorus rutifolius*. The Spleenwort, *Asplenium trichomanes* is restricted to limestone outcrops of the extreme south western corner of the State. The lycopsids, *Phylloglossum drummondii*, *Selaginella gracillima*, *Isoetes drummondii* and the Combfern, *Schizaea fistulosa*, inhabit soils which are saturated or inundated in winter and extremely dessicated in summer. *Lycopodium carolinianum* is limited to peaty swamps which remain moist throughout the year.

The Eastern and Eucla Divisions as well as the southern part of the North-West Division constitute the Eremean Province of Gardner (1942). This vast central area is a region of very low and unreliable rainfall of no marked periodicity (see Table 1). Ferns are rare in this Province and include a few species of the rock-fern genera *Cheilanthes*, *Pleurosorus*, *Gymnogramma* and the ubiquitous *Ophioglossum lusitanicum*. A few species of the aquatic genera, *Marsilea* and *Isoetes* inhabit ephemeral waters of rock pools, clay pans and creek beds.

In arranging the families of pteridophyta for this census the classification of Eames (1936) is followed for the Lycopsida and Psilopsida, whilst the scheme of Copeland (1947) is adopted for the Pteropsida except for the following departures. I have followed several contemporary pteridologists in recognising the segregation of the Thelypteridaceae from the Aspidiaceae of Copeland's scheme and in segregating the Azollaceae from the Salviniaceae as did Christensen (1938) and Holttum (1954). I have also followed the splitting of the Pteridaceae of Copeland into four families as proposed by Alston (1956) and Alston's placing of the genus *Stenochlaena* in the Polypodiaceae rather than in the Blechnaceae of Copeland.

With regard to the genera of ferns represented in Western Australia, I have used Alston's segregation of Copeland's Pteridaceae into Dennstaedtiaceae to include *Microlepia* and *Pteridium;* Lindsaeaceae for *Lindsaea* and Adiantaceae to include *Acrostichum, Adiantum, Ceratopteris, Cheilanthes, Pteris, Anogramma, Gymnogramma* and *Platyzoma*. The last named genus has been referred to the Adiantaceae by Tindale (1962).

LYCOPSIDA

LYCOPODIALES

LYCOPODIACEAE

Lycopodium Linnaeus

Lycopodium carolinianum Linnaeus, *Sp. Pl.* 2: 1104 (1753).

Lycopodium serpentinum Kunze in *Lehm. Pl. Preiss.* 2: 108 (1847).

Lycopodium drummondii Spring, *Mém. Acad. Roy. Belg.* 24: 35 (1849).

Southern temperate Australia, New Zealand, Indonesia, Malaya, Ceylon, Mascarene Is., tropical and S. Africa, New Guinea, N. and S. America.

W. Aust. Restricted to wet, peaty soils in the lower South-West. Muchea (UWA, PERTH), on peaty soils of mound springs. Bayswater, near Perth (NSW). Albany district (UWA, PERTH, MEL), common on peaty soils of swamps, often associated with the pitcher plant, *Cephalotus follicularis*. Marbellup (Diels and Pritzel 1905).

Lycopodium cernuum Linnaeus *Sp. Pl.* 1103 (1753).

Pantropical. Northern Australia and New South Wales. New Zealand.

W. Aust. Charnley River in West Kimberley (PERTH, NSW, Fitzgerald 1916); Cambridge Gulf (MEL).

Lycopodium volubile Forster, *Flor. Ins. Aust. Prod.* 86 (1786).

Malaya, Indonesia, New Guinea to Polynesia, New Caledonia, Northern Australia, New Zealand and Chatham Is.

W. Aust. Glenelg district, West Kimberley (MEL). Spring (1849-50) quoted this species from King George's Sound, W. Aust., but I have not seen any specimen from this region.

Phylloglossum Kunze

Phylloglossum drummondii Kunze in *Bot. Zeitg.* 1: 721 (1843).

Temperate Australia and New Zealand.

W. Aust. Bindoon (PERTH); Kalamunda (UWA) and elsewhere in the Darling Range in shallow loam over granite; Cannington (UWA) and elsewhere in swampy soils of the coastal plain close to the Darling Scarp; Harvey (PERTH); Kojonup (UWA); Yornup (PERTH); Manjimup (UWA); Northcliffe (PERTH); Lake Muir (UWA); Stirling Range (MEL); Albany (PERTH).

SELAGINELLALES

SELAGINELLACEAE

Selaginella de Beauvois

Selaginella ciliaris (Retzius) Spring in *Bull. Acad. Brux.* 10: 231 (1843).

Lycopodium ciliare Retzius, *Obs.* 5: 32, no. 92 (1789).

Lycopodium pumilio R. Brown, *Prod.* 166 (1810).

Selaginella pumilio (R. Brown) Spring in *Bull. Acad. Brux.* 10: 232 (1843).

Selaginella belangeri (Bory) Spring in *Mém. Acad. Roy. Belg.* 24: 242 (1850).

India, southern China to northern Australia (Tindale 1958).

W. Aust. Between Isdell River and Mount Bartlett (PERTH); Isdell River, in clefts of wet rocks (Fitzgerald 1916).

Selaginella gracillima (Kunze) Alston, in *J. Bot. Lond.* 69: 257 (1961).

Lycopodium gracillimum Kunze in *Lehm. Pl. Preiss* 2: 109 (1847).

Selaginella preissiana Spring in *Mém. Acad. Roy. Belg.* 24: 61 (1849).

Temperate Australia.

W. Aust. Widely distributed in the South-West, in habitats ranging from clay flats of coastal and inland swamps to moss swards on granite outcrops. Hutt River near Northampton (PERTH); Hill River (UWA); Greenough and Irwin Rivers (MEL); Chittering (UWA); Mundaring (UWA) and elsewhere in the Darling Range; Guildford (MEL); Cannington (UWA) and elsewhere in swampy places on the coastal plain close to the Darling Scarp; Beverley (UWA); York (MEL); Yorkrakine Rock near Wyalkatchem (UWA); Quairading (UWA); Preston River (MEL); Bridgetown (UWA); Pemberton (UWA); Shannon River (UWA); Franklin River (PERTH); Blackwood River (MEL); Witchcliffe (UWA); Stirling Range (MEL).

Sclaginella uliginosa (Labillardière) Spring in *Bull. Acad. Brux.* 10: 136 (1843).

Lycopodium uliginosum Labillardière, *Fl. N. Holl. Pl. Sp.* 2: 104, t. 251 f. 2 (1806).

Tropical and southern Australia.

W. Aust. Apparently rare. King George's Sound (MEL).

ISOETALES

ISOETACEAE

Isoetes Linnaeus

Isoetes drummondii A. Braun in *Monatsber. Akad. Wiss., Berl.* 593 (1863) 1864 and 542 (1868).

Temperate Australia.

W. Aust. Banks of creeks, shallow loams over granite and elsewhere in clay or sandy soils becoming inundated with water in winter. Mingenew (UWA); Toodyay (Pfeiffer 1922); York (UWA); Brookton (UWA); Tinkurrin (UWA); Cannington and elsewhere near Perth (PERTH, UWA); Harvey (PERTH); Bridgetown (UWA); Wilgarup (PERTH); Hamersley Range (Diels and Pritzel 1905).

Isoetes humilior F. Mueller ex A. Braun in *Linnaea* 25: 722 (1853).

Widespread in temperate Australia (Willis 1962).

W. Aust. Middle Island, Recherche Arch., (MEL); Mt. Belches (MEL); Ballidu (MEL). Inhabiting shallow and ephemeral waters of pools on granite outcrops.

Isoetes spp.

The herbarium of the University of Western Australia has collections of small aquatic *Isoetes* from rock pools in many localities in the southern part of Western Australia. Preliminary investigation of these collections has shown that there is considerable variation of morphology in populations from different localities. None of these forms satisfactorily agree with the description of *Isoetes humilior*. These forms and the western populations of the swamp species, *Iscetes drummondii* require thorough investigation.

PSILOPSIDA

PSILOTALES

PSILOTACEAE

Psilotum Swartz

Psilotum nudum (Linnaeus) Grisebach in *Veget. d. Karaiben* 130: 1857.

Lycopodium nudum Linnaeus, *Sp. Pl.* 2, 1100 (1753).

Psilotum triquetrum Swartz in *Schrad. J. Bot.* 109: (1800)² (1801).

Pantropical with extensions into moist subtropical regions. In Australia, *Psilotum* occurs in northern tropical Australia, Central Australia, New South Wales, and the Grampians in Victoria. It also occurs on Lord Howe and Norfolk Islands and in New Zealand.

W. Aust. Sprigg and Charnley Rivers in the Kimberley Division (PERTH, Fitzgerald 1916). A recent collection from Galena on the Murchison River (UWA), has considerably extended the known southerly limit of this species in Western Australia (Smith and Butler 1961).

PTEROPSIDA

OPHIOGLOSSALES

OPHIOGLOSSACEAE

Helminthostachys Kaulfuss

Helminthostachys zeylanica (Linnaeus) Hooker, *Gen. Fil. t.* 47 (1840).

Osmunda zeylanica Linnaeus, *Sp. Pl.* 2: 1063 (1753).

Ceylon and India through Malaysia and Formosa to the Caroline Islands and New Caledonia (Copeland 1947). Tropical Australia.

W. Aust. Marie Springs on the Prince Regent River, West Kimberley (PERTH).

Ophioglossum Linnaeus

Ophioglossum lusitanicum ssp. coriaceum (Cunningham) Clausen in *Mem. Torrey bot. Club* 19: 161 (1938).

Ophioglossum coriaceum Cunningham in *Hook. Compan. bot. Mag.* 2: 361 (1837).

Bolivia, Chile, Easter Is., New Caledonia, Australia (including Tasmania) and New Zealand (Clausen 1938).

W. Aust. Cape Range (PERTH); 80 miles south of Learmonth (PERTH); Minilya River (PERTH); Mingenew (Andrews 1902, Diels and Pritzel 1905); New Norcia (UWA); Wongan Hills (PERTH, MEL); Toodyay (Diels and Pritzel 1905); Goomalling (PERTH); Bullfinch (PERTH); Bindoon (PERTH); Bruce Rock (UWA); Yorkrakine Rock near Wyalkatchem (UWA); Kalamunda (UWA) and elsewhere in the Darling Range; Guildford and Fremantle (Fitzgerald 1901); Medina (PERTH); Noman's Lake east of Narrogin (UWA); Pallarup Rocks, S.E. of Lake King (PERTH); Porongurup Range (UWA); Cue (PERTH); Payne's Find (PERTH);

Leonora (PERTH); Laverton (PERTH); Mt. Beadell, north of Warburton Range (PERTH); Karonie (PERTH); Balladonia (MEL).

FILICALES

SCHIZAEACEAE

Lygodium Swartz

Lygodium microphyllum (Cavanilles) R. Brown, *Prod.*, 162 (1810).

Ugena microphylla Cavanilles in *Ic. Descr. Pl.* 6: 76, t. 595 (1801).

Lygodium scandens (Linnaeus) Swartz in *Schrad. J. Bot.* 106 (1800)[2] (1801).

Lygodium scandens var. *microphyllum* (Cavanilles) Luerssen, in *J. Mus. Godeffr.* 6: 4 (1874).

Ophioglossum scandens Linnaeus, *Sp. Pl.* 1063 (1753).

Tropical and subtropical Africa, Asia and Australia, Polynesia.

W. Aust. Common throughout the Kimberley Division, in the river forest formation, (Gardner 1923). Isdell, Sprigg, Hann, Charnley and Calder Rivers, Dillon's Springs and Sunday Is., in West Kimberley (Fitzgerald 1916). Sunday Is. (NSW); Isdell River (PERTH); Imidjin Creek in McDonald Range (PERTH); Deception Range (PERTH, CANB); Thompson's Springs on Ord River (PERTH); Sprigg River in Synnott Range (PERTH); Moran River (PERTH); west of Cambridge Gulf (MEL).

Schizaea J. Smith

Schizaea fistulosa Labillardière, *Nov. Holl. Pl. Specim.* 2: 103 (1807).

Southern Australia, New Zealand, Chile, Borneo, Madagascar, Fiji, New Caledonia (Holttum 1959).

W. Aust. Restricted to peaty and swampy soils of the South-West. Muchea (PERTH); Bayswater (UWA); Pemberton (PERTH); Northcliffe (PERTH); Albany (PERTH, AD. Andrews 1902); Walpole (UWA); Blackwood River (PERTH); King George's Sound (PERTH, Diels and Pritzel 1905); Plantagenet district (NSW, leg. Preiss).

GLEICHENIACEAE

Dicranopteris Bernhardi

Dicranopteris linearis (Burmann f.) Underwood, in *Bull. Torrey Bot. Club* 34: 250 (1907).

Polypodium lineare Burmann f. *Fl. Ind.* 235. t. 67. f. 2. (1768).

Gleichenia dichotoma Hooker, *Sp. Fil.* 1: 12 (1844).

Gleichenia linearis (Burmann f.) Clarke in *Trans. Linn. Soc. Lond.* 1: 428 (1880).

Gleichenia hermannii R. Brown, *Prod.* 161 (1810).

Dicranopteris hermannii (R. Brown) Nakai in *Bull. Nat. Sci. Mus. Tokyo* No. 29: 60 (1950).

Tropical and subtropical regions of Africa, Asia. Malaysia, Australia and Polynesia (Pichi-Sermolli 1962). Tropical America (Nakai 1950).

W. Aust. Confined to wet habitats in the Kimberley Division. Hunter River at York Sound (MEL, leg. Cunningham); Charnley River (PERTH, Fitzgerald 1916); Imidjin Creek (PERTH); Mt. Agnes (PERTH); Prince Regent River (Gardner 1923).

DENNSTAEDTIACEAE

Microlepia Presl

Microlepia speluncae (Linnaeus) Moore, *Index Fil.* xciii (1857).

Polypodium speluncae Linnaeus, *Sp. Pl.* 2: 1093 (1753).

Pantropical, extending south to Madagascar and New Zealand (Copeland 1947).

W. Aust. West Kimberley (PERTH). A single barren specimen from the Brockman Expedition of 1901.

Pteridium Scopoli

Pteridium esculentum (Forster f.) Nakai in *Bot. Mag. Tokyo* 39: 108 (1925).

Pteris esculenta Forster f., *Pl. Escul.* 74 (1786).

Temperate Australia, New Caledonia, New Zealand and Polynesia.

W. Aust. Common in the lower South-West between Perth and Albany and particularly abundant in the Karri forest formation. According to Gardner and Bennetts (1956), this species extends as far north as Port Gregory, north of Geraldton. Gingin (PERTH); Swan River (MEL, PERTH); Harvey (UWA); Margaret River (PERTH); Pemberton (UWA); Northcliffe (UWA); Shannon River (UWA); Wilson's Inlet (NSW); Bow River (NSW, UWA); Blackwood River (MEL); Porongurup Range (UWA); King George's Sound (UWA, MEL).

LINDSAEACEAE

Lindsaea Dryander in J. Smith

Lindsaea ensifolia Swartz in *Schrad. J. Bot.* 77 (1800)[2], (1801).

Schizoloma ensifolium (Swartz) J. Smith in *J. Bot.* 3: 414 (1841).

West and South Africa, Madagascar, Tropical Asia, Northern Australia to Polynesia (Tindale 1958).

W. Aust. Throughout the Kimberley. Mitchell River, in moist humid valleys among sandstone rocks on banks of streams (Gardner 1923). Lawley River (PERTH); Charnley River (PERTH); Thompson's Springs on the Ord River (PERTH, MEL); Napier Broome Bay (MEL); Derby (MEL); Grant Range (NSW).

Lindsaea linearis Swartz in *Schrad. J. Bot.* 78 (1800)[2], (1801).

Throughout southern Australia and Tasmania, New Caledonia, New Zealand.

W. Aust. Common in the sclerophyllous forests and scrub country of the lower South-West. Jarrahdale (PERTH) and elsewhere in the Darling Range. Vasse River (MEL); Donnybrook (UWA); Collie (UWA); Bridgetown (UWA); Manjimup (UWA) and elsewhere in the Karri forest; Yallingup and Cape Naturaliste (Domin 1912); Nornalup (UWA); Bow River (NSW, UWA); Scott River (UWA); Mt. Barker (PERTH); Porongurup Range (MEL); Albany (PERTH, MEL); Mt. Le Grande (PERTH).

ADIANTACEAE

Acrostichum Linnaeus

Acrostichum speciosum Willdenow, *Sp. Pl.* 5: 117 (1810).

Tropical Asia and Australia, in salt or brackish swamps at the back of mangroves or along tidal creeks (Tindale 1958).

W. Aust. Kimberley and North-West. East Kimberley (PERTH); Isdell River near Walcott Inlet (PERTH); Sunday Is., (PERTH, NSW, Fitzgerald 1916 as *Acrostichum aureum* L.). Derby (NSW); Nickol Bay (MEL). The specimens in PERTH have been referred to as *A. aureum* L., but are in fact, *A. speciosum*.

Adiantum Linnaeus

Adiantum aethiopicum Linnaeus, *Syst. Nat. ed.* 10, 2: 1329 (1759).

Australia and New Zealand, South Africa (Pichi-Sermolli 1957).

W. Aust. Confined to the lower South-West, along creeks and rivers in the Jarrah and Karri forests, or in the shelter of rock outcrops. Mundaring (PERTH); Serpentine River (UWA, MEL) and elsewhere in the Darling Range. Harvey River (MEL); Bunbury (MEL); Donnybrook (PERTH); Meelup (UWA); Collie (PERTH); Bridgetown (PERTH); Margaret River (UWA); Blackwood River (MEL); Manjimup (UWA); Pemberton (UWA, MEL, PERTH); Walpole (UWA); Lake Muir (MEL); King George's Sound (MEL); Porongurup Range (UWA, MEL, NSW); Stirling Range (MEL).

Adiantum capillus-veneris Linnaeus, *Sp. Pl.* 2: 1096 (1753).

Tropical, subtropical and warm temperate zones of the world (Pichi-Sermolli 1957).

W. Aust. Wittenoom Gorge, in Hammersley Range (PERTH, UWA, MEL). Apparently very rare and restricted to oases in otherwise arid country, as is the case for this species in arid parts of Ethiopia (Pichi-Sermolli 1957).

Adiantum philippense Linnaeus, *Sp. Pl.* 2: 1094 (1753).

Adiantum lunulatum Burmann f., *Fl. Ind.*, 235 (1768).

Tropics of the Old World (Pichi-Sermolli 1957).

W. Aust. Kimberley Division. King Sound (Fitzgerald 1916); Wingrah Pass in Napier Range (PERTH, Fitzgerald 1916); on limestone near Barker River Gorge in Napier Range (PERTH, Gardner 1923); Derby (NSW).

Anogramma Link

Anogramma leptophylla (Linnaeus) Link, *Fil. Sp. cult.*, 137 (1841).

Polypodium leptophyllum Linnaeus, *Sp. Pl.* 2: 1092 (1753).

Pityrogramma leptophylla (Linnaeus) Domin in *Publ. Fac. Sci. Univ. Charles*, No. 88: 9 (1928).

Grammitis leptophylla Swartz, *Syn. Fil.*, 23: 218 (1806).

Gymnogramma leptophylla Desvaux, *Mag. Ges. Nat. Freunde Berl.* 5: 305 (1811).

Temperate and subtropical regions of the Old and New Worlds.

W. Aust. Common in shaded recesses of both limestone and granitic rocks throughout the South-West. Helena River and elsewhere in the Darling Range (UWA); limestone cliffs in the King's Park, Perth (UWA, NSW); Hill River Springs (MEL); Yanchep (UWA); Claremont, near Perth (Andrews 1902); Mandurah (UWA); Yallingup (PERTH, Ostenfeld, 1918); Margaret River (UWA); Vasse River (MEL, leg. Preiss); Porongurup Range (UWA); Lake Deborah (Helms in Mueller and Tate 1896).

Ceratopteris Brongniart

Ceratopteris thalictroides (Linnaeus) Brongniart in *Bull. Sci. Soc. Philom.* 186 (1821)[2] (1822).

Acrostichum thalictroides Linnaeus, *Sp. Pl.* 2. 1070 (1753).

Widespread in tropical East Africa, Madagascar, the Seychelles and Mascarene Islands, and in tropical and subtropical Asia and Australia (Pichi-Sermolli 1957).

W. Aust. An aquatic of river margins and marshes in the Kimberley and North-West Divisions. Isdell, Adcock and Charnley Rivers, Woolybut Creek, in the Kimberleys (Fitzgerald 1916) (PERTH); Walcott Inlet, Sale, Glenelg and Calder Rivers, Bachsten Creek, in the Kimberley (Gardner 1923, PERTH); Millstream on the Fortescue River (PERTH).

Cheilanthes Swartz

Cheilanthes distans (R. Brown) Mettenius, *Abh. senckenb. naturf. Ges.* 3: 69 (1859).

Notholaena distans R. Brown, *Prod.* 146 (1810).

Throughout Australia except Tasmania, New Zealand, Polynesia, Celebes.

W. Aust. Inhabiting shallow loam of rocky places throughout the South-West and South-East. Karunjie Station, Kimberley (CANB); Darlington and elsewhere in the Darling Range (PERTH, UWA, MEL); Toodyay (PERTH); York (MEL); Harvey (MEL); Lowden (MEL, NSW); Mount Magnet (Moore, S. le M., 1899); Kalgoorlie (Ostenfeld 1918); Salt River (MEL); West River, Eyre District (MEL); Eucla (MEL); Fraser Range (PERTH, MEL).

Cheilanthes lasiophylla Pichi-Sermolli in *Webbia* 8: 209 (1951).

Nothochlaena canescens Kunze in *Lehm. Pl. Preiss.* 2: 110 (1846).

non *Cheilanthes canescens* Kunze 1847a.

Nothlaena vellea sens. auctt. non strict. R. Brown, *Prod.* 146 (1810).

Notholaena brownii sens. auctt. Aust. plur., non Desveaux, *Prod.* 220 (1827).

Australia, particularly in the more arid regions.

W. Aust. Deception Range, West Kimberley (CANB); Abydos, S. of Port Hedland (MEL); Wittenoom Gorge (MEL); Cape Range (PERTH); Gascoyne River (MEL); Champion Bay (MEL); Yandanooka (UWA); Mundaring (UWA); Southern Cross (UWA); Kellerberrin (AD); Mt. Caroline (MEL); Lake Barlee (UWA, MEL); Lawlers (PERTH); Glen Cummin Gorge, Rawlinson Range (AD); Warburton Mission (PERTH); Norseman (PERTH); Fraser Range (MEL, PERTH); Balladonia (MEL).

Cheilanthes tenuifolia (Burmann f.) Swartz, *Syn. Fil.* 129 (1806).

Trichomanes tenuifolium Burmann f., *Fl. Ind.* 237 (1768).

India and China through Malaysia to Australia and Polynesia. New Zealand.

W. Aust. Throughout the State and abundant in the South-West. Mostly inhabiting shallow loam over granite, often forming extensive swards in both shaded and sunny situations. Cambridge Gulf (MEL); Camden Sound (MEL); Lennard River (PERTH); Isdell River (PERTH); Prince Regent River (MEL, PERTH); Synnott Range (PERTH); King Sound (NSW); Derby (NSW); and elsewhere in the Kimberley. Nickol Bay (MEL); Quartz Hill near Roebourne (PERTH); Cape Range (PERTH); Marble Bar (PERTH); Wittenoom (MEL); Gascoyne River (MEL); Beringarra (CANB); Meekatharra (PERTH); Mt. Magnet (PERTH, MEL) and elsewhere in the North-West Division. Coolgardie (NSW); Lake Barlee (MEL); Laverton (PERTH); Warburton Range (PERTH); Lake Deborah (MEL); Rawlinson Range (MEL) and elsewhere in the Eastern Division. Murchison River (MEL, PERTH); Geraldton (MEL); Northampton (PERTH); Dandaragan (UWA); Wongan Hills (UWA); Yorkrakine (UWA); Darlington and elsewhere in the Darling Range (PERTH, MEL, UWA); York (MEL); Kellerberrin (UWA, NSW); Busselton (MEL); Wagin (MEL); Narrogin (UWA); Blackwood River (MEL); Bow River (UWA); Cape Leeuwin (MEL); Pemberton (MEL); Porongurup Range (UWA, MEL, NSW); Stirling Range (NSW, MEL, PERTH); King George's Sound (MEL, UWA); Bremer Bay (MEL, PERTH) and elsewhere in the South-West Division. Fraser Range (MEL); Mt. Ragged (MEL); Recherche Arch., (MEL, Willis 1953); Cape Arid (MEL); Israelite Bay (MEL); and elsewhere in the Eastern Division.

Cheilanthes vellea (R. Brown) F. Mueller in *Fragmenta* 5: 123 (1866).

Notholaena vellea R. Brown, *Prod.* 146 (1810).

Notholaena brownii Desveaux, *Prod.* 220 (1827).

Tropical and more arid parts of subtropical Australia.

W. Aust. Napier Broome Bay (MEL); Cambridge Gulf (MEL); Ord River (MEL); In sandy soil on rises amongst quartzite rocks—Prince Regent, Mitchell and King Edward Rivers (Gardner 1923, PERTH); Glenelg River (PERTH); King Sound (MEL); Talga Station in Barlee Range (PERTH); Carson River (MEL); Quartz Hill near Roebourne (PERTH); Yorkrakine Rock near Wyalkatchem (UWA).

Gymnogramma Desveaux

Gymnogramma reynoldsii (F. Mueller) Black, *Flora Sth. Aust.* 40 (1922).

Grammitis reynoldsii (F. Mueller) ex Bentham, *Flora Aust.*, 8: 775 (1878).

Nothochlaena reynoldsii F. Mueller, in *Fragmenta* 8: 175 (1874).

Arid interior of Australia.

W. Aust. Cavenagh Range (Mueller and Tate 1896). The few other records of this rare fern include Flinders, Everard, Berksgate and Musgrave Ranges in Sth. Aust. (AD); Stanley Chasm in the McDonnell Range, Mt. Olga in Northern Territory (MEL); Ulambaura Springs, Northern Territory (PERTH); Stuart Range, Northern Territory (MEL).

Copeland (1947) claims that *Gymnogramma* Desveaux is a synonym of *Gymnopteris* Bernhardi and suggests that this fern presumably belongs to *Paraceterach* (F. Mueller) Copeland. Dr. M. D. Tindale is presently investigating the uncertain systematic position of this fern.

Platyzoma R. Brown

Platyzoma microphyllum R. Brown, *Prod.* 160 (1810).

Gleichenia platyzoma F. Mueller, *Veg. Chatham Is.* 63 (1864).

A monotypic genus confined to arid parts of tropical and subtropical Australia. West Australia, Northern Territory, Queensland, New South Wales, South Australia.

W. Aust. Throughout the Kimberley Division. Napier Broome Bay (MEL); Glenelg River (MEL, PERTH); Mt. Agnes (PERTH); Gibb River (PERTH, MEL, NSW); Ord River (PERTH, MEL, NSW, CANB); Isdell River (PERTH); Sources of the Calder, Charnley, Glenelg, Prince Regent, Moran and King Edward Rivers (Gardner 1923); Burt Range (UWA); "common on the central plateau around Mt. Agnes, in sandy, swampy soils in open places, forming dense colonies of many feet in diameter"—Gardner 1923.

Pteris Linnaeus

Pteris vittata Linnaeus, *Sp. Pl.* 2: 1074 (1753).

Widely distributed in the tropics and subtropics of the Old World (Holttum 1954). Tropical Australia, extending into New South Wales and Victoria on the east coast and to the south west of Western Australia.

W. Aust. Wittenoom Gorge in Hammersley Range (PERTH, UWA, MEL); Yanchep (UWA); Yallingup Caves (Fitzgerald 1903 as *Pteris longifolia* L.) Deepdene, near Augusta (UWA).

POLYPODIACEAE

Microsorium Link

Microsorium scolopendria (Burmann f.) Copeland in *Univ. Calif. Publ. Bot.* 16: 112 (1929).

Phymatodes scolopendria (Burmann f.) Ching in *Contr. Inst. Bot. Nat. Acad. Peiping* 2: 63 (1933).

Polypodium scolopendria Burmann f. in *Fl. Ind.* 232 (1768).

Polypodium phymatodes Linnaeus, *Mant. Pl.*, 306 (1771).

Tropical Africa, Ceylon, Indo-China, Malaysia to Polynesia and tropical Australia.

W. Aust. Kimberley. Sunday Island (Fitzgerald 1916); Prince Regent River (Gardner 1923); King River (PERTH, Fitzgerald 1916).

Stenochlaena J. Smith

Stenochlaena palustris (Burmann f.) Beddome, *Suppl. Ferns Brit. Ind.* 26 (1876).

Polypodium palustre Burmann f. *Flora Ind.*, 234 (1768).

Acrostichum scandens (Swartz) Hooker, *Sp. Fil.* 5: 249 (1864).

Asia, Malaysia, Polynesia.

W. Aust. Synnott Range near Sprigg River (PERTH); Prince Regent River (PERTH); Sprigg and Charnley Rivers, in wet spots (Fitzgerald 1916).

DAVALLIACEAE

Nephrolepis Schott

Nephrolepis sp.

W. Aust. In boggy spots, Sprigg, Charnley and Hann Rivers, MacNamara Creek, base of Artesian Range, Edkins Range, Sunday Is., (Fitzgerald 1916, as *N. exaltata* (L.) Schott); Synnott Range (PERTH, as *N. exaltata* (L.) Schott).

ASPLENIACEAE

Asplenium Linnaeus

Asplenium adiantoides (Linnaeus) Lamarck, *Encycl. méth. Bot.* 2: 309 (1786).

Trichomanes adiantoides Linnaeus, *Sp. Pl.* 2: 1098 (1753).

Asplenium praemorsum Swartz, *Nov. Gen. & Sp. Pl. Prod.* 130 (1788).

Tropical and subtropical parts of all continents (Willis 1962).

W. Aust. Throughout the lower South-West and Eucla Divisions. Inhabiting fissures of granitic rocks or epiphytic on trees and fallen logs of the Karri forest. Leschenault (MEL); Harvey River (MEL); Mornington Mills (PERTH); Margaret River (UWA); Blackwood River (MEL); Mt. Cheedalup (PERTH); Pemberton (UWA, PERTH, MEL); Epiphytic on *Casuarina decussata* (Willis 1962); Warren River (MEL); Shannon River (MEL); Walpole (UWA); Bow River (UWA); Torbay (PERTH); Albany (MEL, PERTH, UWA); Porongurup Range (UWA, PERTH, MEL, NSW); Stirling Range (PERTH, MEL, UWA); Bald Is. (PERTH); Whoogarup Range (PERTH).

Asplenium flabellifolium Cavanilles, *Descr. Plant.* 257 (1802).

Temperate Australia, New Zealand.

W. Aust. Confined to damp, shaded places, usually amongst rocks, in the lower South-West from Karridale to Albany, Stirling Range and eastward to Israelite Bay. Karridale (MEL); Yallingup (UWA); Blackwood River (MEL); Pemberton (UWA, PERTH); Warren River (MEL); Nornalup (UWA); Albany (MEL, PERTH); Lake Muir (MEL); Porongurup Range (UWA, PERTH, MEL, NSW); Stirling Range (PERTH, Domin 1912, Lehmann 1846); Esperance (MEL); Lucky Bay (R. Brown 1810); Mount Ragged (PERTH).

Asplenium obtusatum Forster f., *Flor. Ins. Aust. Prod.* 80 (1786).

Asplenium marinum var. *obtusum* F. Mueller in *Fragmenta* 5: 188 (1866).

Southern Australia, Sub-antarctic Islands, Tristan Da Cunha, Chile.

W. Aust. Breaksea Island in King George's Sound, amongst rocks (MEL, leg. G. Maxwell 1866; det.. *Asplenium marinum* var. *obtusum* by F. Mueller 1866: 188). It is the only record of this maritime fern for W. Aust. Mueller (1896) listed this species again for Western Australia, probably in reference to the Maxwell collection from Breaksea.

Asplenium trichomanes Linnaeus, *Sp. Pl.* 2: 1080 (1753).

Temperate regions of the Old and New Worlds; mountainous districts of the tropics. Throughout southern Australia and New Zealand.

W. Aust. Common on limestone outcrops in the caves district between Capes Naturaliste and Leeuwin, in the lower South-West. Yallingup (UWA, PERTH, Ostenfeld 1921); Margaret River (UWA, NSW); Karridale (UWA); Augusta (UWA); Mount Manypeaks (PERTH).

Pleurosorus Fée

Pleurosorus rutifolius (R. Brown) Fée. *Mém. Fam. Foug.* 5: 179 (1852).

Grammitis rutaefolia R. Brown, *Prod.* 146 (1810).

Throughout Australia and New Zealand.

W. Aust. A rock fern of shaded recesses of granite, metasediments and limestone throughout the South-West. Laverton (PERTH); Coolgardie and Bullabulling (Moore, S. le M. 1899); Merredin Peak (PERTH); Wongan Hills (MEL); Yorkrakine Rock (UWA); York (MEL, UWA); Kelmscott (UWA); Darlington (Andrews 1902); Dwellingup (UWA); Narrogin (UWA); Wagin (MEL); Williams River (MEL); Mt. Stirling, S. of Kellerberrin (UWA); Stirling Range (MEL, NSW); Blackwood River (MEL); Albany (MEL); Whoogarup Range (PERTH); Esperance (MEL); Fraser Range (MEL, PERTH); Mt. Ragged (MEL); Lake Deborah (MEL. Helms in Mueller and Tate 1896); Madura Pass (MEL); Eucla (MEL, Willis 1959).

Pleurosorus subglandulosus (Hooker & Greville) Tindale in *Vic. Nat.* 73: 169 (1957).

Gymnogramma subglandulosa Hooker & Greville, *Icon. Fil.* 1: t. 91 (1827).

W. Aust. W. Aust. (Drummond No. 1000 in MEL); Gooseberry Hill, Darling Range (NSW); Lesmurdie, Darling Range (UWA); Swan View (PERTH); Mundaring Weir (PERTH); eastern sources of the Swan River (MEL); Chittering (PERTH); Wongan Hills (PERTH); Mornington Mills (PERTH); Glen Cumming Gorge near Giles, Rawlinson Range (AD).

Tindale (1957) claims this taxon to be specifically distinct from *P. rutifolius* because of the presence of glandular hairs on the fronds, whereas *P. rutifolius* has only non-glandular hairs. Also, *P. subglandulosus* is considered to be a larger plant than *P. rutifolius.* Willis (1962) regards this taxon as a variety of *P. rutifolius* partly on the grounds that, in Victoria, there occur plants with a mixture of both hair types as well as plants with either type of hairs.

I have examined 43 specimens of *Pleurosorus* from a wide area of distribution in Western Australia, and have found 33 plants with non-glandular hairs and 10 plants, as cited above, with glandular hairs. I doubt that there is any real difference in stature or robustness of fronds between the two taxa; our material of both varies considerably in frond size over the range of distribution of the genus.

A cytotaxonomic study of the two taxa would be interesting and might establish the validity of *P. subglandulosus* as a separate entity.

THELYPTERIDACEAE

Cyclosorus Link

Cyclosorus gongylodes (Schkuhr) Link, *Hort. Berol.* 2: 128 (1833).

Dryopteris gongylodes (Schkuhr) O. Kuntze, *Rev. Gen. Pl.* 2: 811 (1891).

Aspidium goggilodus Schkuhr. *Kryp. Gew.* 1: 193 (1809).

Aspidium unitum Swartz in *Schrad. J. Bot.* 32 (1800)[2], (1801).

Pantropical. Throughout northern Australia, extending to New South Wales in the east and thence to New Zealand where it is confined to thermal regions (Dobbie and Crookes 1951).

W. Aust. Throughout the Kimberley Division and extending sparsely to the South-West Division. "Aquatic, growing in running water along banks of streams. Prince Regent, Mitchell, Moran, King Edward and Drysdale Rivers in the Kimberley"— Gardner (1923) (PERTH); McNamara Creek and Charnley River in Kimberley (PERTH); Murchison River (PERTH); Lennard's Brook, near Gingin (UWA, PERTH); Wallcliff, at the mouth of the Margaret River (MEL).

BLECHNACEAE

Blechnum Linnaeus

Blechnum orientale Linnaeus, *Sp. Pl.* 2, 1535 (1763).

Tropics of Asia, Australia and the Pacific (Holttum 1954).

W. Aust. Throughout the Kimberley Division. Thompson's Springs on the Ord River (PERTH); Prince Regent River (PERTH); Imidjin Creek in McDonald Range (PERTH).

MARSILEACEAE

Marsilea Linnaeus

Marsilea angustifolia R. Brown. *Prod.* 167 (1810).

Northern and south eastern Australia to Victoria.

W. Aust. Throughout the Kimberley Division. "Bases of Mounts House, Clifton, Hamilton and Brennan. In wet spots chiefly around billabongs"—Fitzgerald 1916. In billabongs near the Isdell River (Gardner 1923); Mt. Hamilton (PERTH).

Marsilea drummondii A. Braun in *Linnaea* 25: 721 (1852).

Marsilea muelleri A. Braun in *Linnaca* 25: 721 (1853).

Australia.

W. Aust. Clay pans and creeks in the North-West, South-West and Eastern Divisions. Gascoyne River (UWA, Diels and Pritzel 1905); Gascoyne Junction (UWA); Murchison River Bridge (UWA); Mingenew (UWA); New Norcia (PERTH); Miling (PERTH); Mogumber (PERTH); York (PERTH); Upper Swan (UWA); Giles, in Rawlinson Range (AD).

Marsilea hirsuta R. Brown, *Prod.* 167 (1810).

Australia, excepting Tasmania.

W. Aust. Walcott Inlet, Duck Pool, Isdell River and near Mt. Marmion (Gardner 1923, PERTH); Gogo Station on Fitzroy River (PERTH); Carson and Meda Rivers (PERTH); South Barlee Range (PERTH); Yalgoo (PERTH); Geraldton (UWA); Rawlinson Range (AD).

Marsilea mutica Mettenius in *Ann. Sci. Nat.*, *ser.* 4. 15: 88 (1861). Tindale in *Contr. N.S.W. natn. Herb.* 2: 8 (1953).

Marsilea brownii A. Braun in *Monatsber. Konigl. Preuss. Akad. Wiss. Berl.* 418 (1863) (1864).

Australia and New Caledonia.

W. Aust. Upper Carson River (PERTH, Gardner 1923); Gascoyne River (Mueller 1883); Nookawarra and Glenorn Stations in the North-West (PERTH); Mingenew (UWA); Waroona (PERTH); Coolup (PERTH); Fraser Range (Mueller and Tate 1896); Mt. Squires in Barrow Range (AD).

Tindale (1953), after comparing the holotypes of *Marsilea mutica* and *M. brownii* concludes they are conspecific. As Mettenius' name antedates that of Alexander Braun the species in Australia must now be known as *M. mutica*.

Pilularia Linnaeus

Pilularia novae-hollandae A. Braun in *Monatsber. Konigl. Preuss. Akad. Wiss. Berl.* 435 (1863) (1864).

Pilularia globulifera sensu Bentham, *Flora Aust.* 7: 684 (1878).

Australia.

W. Aust. An apparently rare species. Swan River (Drummond); Boyanup (PERTH); Harvey (PERTH). The Boyanup habitat is marshy depressions in pasture land.

AZOLLACEAE

Azolla Lamarck

Azolla filiculoides Lamarck in *Encycl. méth. Bot.* 1: 343 (1783).

Azolla rubra R. Brown, *Prod.* 167 (1810).

Azolla filiculoides Lamarck var. rubra (R. Brown) Strasburger, *Über Azolla* 78 (1873).

Australia and New Zealand. North and South America. Naturalised in Europe and Great Britain.

W. Aust. Common in still waters of swamps and creeks of the coastal plain near Perth. Moore River (MEL, PERTH, UWA); Gingin (UWA); Wanneroo, Bayswater, Bibra Lake and elsewhere near Perth (UWA, PERTH).

NATURALISED ESCAPES

CYATHEACEAE

Cyathea J. Smith

Cyathea australis (R. Brown) Domin, *Pteridophyta* 262 (1929). Tindale in *Contr. N.S.W. natn. Herb.* 2: 349 (1956).

Alsophila australis R. Brown, *Prod.* 158 (1810).

Victoria, Tasmania, New South Wales, Queensland.

W. Aust. Naturalised along the banks of Nerrigen Brook and adjacent creeks at Bedfordale. This treefern population developed from a single specimen planted by Mr. O. J. Dowell in 1934 in an orchard property on the Nerrigen Brook. About a hundred mature plants are at present to be seen along the brook and tributary creeks. Prothalli and sporelings are abundant on creek embankments where Bracken, scrub and grasses afford sufficient shelter.

SALVINIACEAE

Salvinia Adanson

Salvinia auriculata Aublet, *Hist. Pl. Guiane franc.*, 969 (1775).

Central and South America.

W. Aust. An ornamental of garden ponds. A naturalised escape in the freshwater reaches of the Canning River (UWA, PERTH), and in a swamp at Harvey (UWA, PERTH). The Harvey collection was noted by Smith (1960) under the name of *Salvinia rotundifolia*.

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2.—The Warburton Range nickel-rich ataxite

by G. J. H. McCall* and H. B. Wiik†

Manuscript received 16th February, 1965; accepted 22nd June, 1965.

Abstract

A new find of a large single mass of meteoritic iron in the Warburton Range area of Western Australia has proved, on sectioning, etching, and mineragraphic study to be a nickel-rich ataxite containing an unusually high percentage of nickel and cobalt in the metal phase. Chemical analysis shows that it contains 19.08 per cent nickel and cobalt. The meteorite is a single mass showing surface ablation markings and details of external features are briefly given.

Introduction

The Warburton Range iron meteorite, a new find in Western Australia, was briefly mentioned in a Catalogue of Western Australian meteorite collections (McCall & de Laeter 1965, p. 18) and in a report on the progress of meteoritics in Western Australia (McCall 1965). In this paper more complete details of this new and rare iron meteorite, now confirmed as a nickel-rich ataxite, are given.

Details of the find

In December 1963 or January 1964 two prospectors working near the Warburton Mission, in the eastern part of Western Australia, recovered a single mass of meteoritic iron weighing 125½ lbs. This mass was brought in to the Native Welfare Department at Kalgoorlie by the finders, Messrs. H. Gill and G. Sims and, after identification of the mass as meteoritic iron by members of the staff of the School of Mines, Kalgoorlie, it was lodged in the collection of the Western Australian Museum as Specimen No. 12295.

This discovery was made 12 miles south of the Warburton Mission on sand amid broken outcrops of sandstone, and reports indicate that the meteorite was lying on the surface, not buried. The location was initially given as 25 miles south-west of the Warburton Mission, but a more accurate position has been given by Mr. J. H. Lord (fig. 1) and the approximate co-ordinates are: East 126° 40′; South 26° 17′.

External features

The single mass is of crudely conical form (fig. 2, A, B, C) and shows a distinct flattened sole (fig. 2, D) which appears rough and weathered, suggesting that this is the surface upon which the mass rested from the time of fall to the time of discovery. The other faces are, in contrast, less eroded and show a shiny film of oxide coating. This film is thin, however, as is shown in the cut section illustrated in figure 3, and the interior of the meteorite is uniformly fresh. Regmaglypt patterns are present on the three side faces of the cone, and weakly so on the basal face. Clearly it is a single meteorite which was not fragmented at any time during the later stages of atmospheric flight or on impact. However, no distinct orientation of surface markings indicating attitude in atmospheric flight can be detected, though such a pattern is typical of single, unfragmented meteorites.

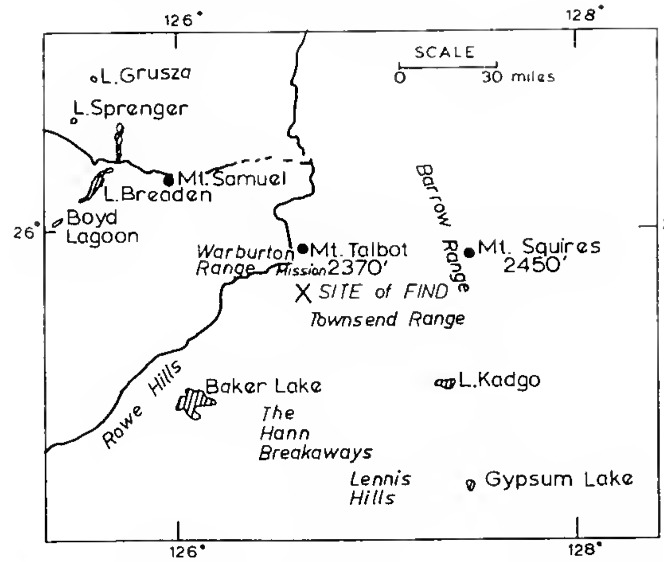

Figure 1.—Sketch map showing the location of the Warburton Range meteorite. Solid lines are tracks.

Specific gravity

The freshness of the mass and small size and scarcity of troilite inclusions means that the specific gravity values obtained will be consistent. Measurement on a cut section gave a value of 8.05.

Internal structure

When first examined this meteorite was believed to be an octahedrite, for a pattern of intersecting linear markings was noticed on the shiny outer surface, suggesting a weathered-out Widmanstatten pattern, such as is evident on Tieraco Creek (McCall & de Laeter 1965, p. 50). It was secured for the Museum more on account of its external features and size rather than because of any suspected rare quality. However, after cutting and etching with 8 per cent. nital reagent no distinct pattern was developed, even after etching for several minutes. On careful examination it was found that there is evident. (a) very fine dark mottling and minute white specks within the dark mottles, and (b) very sparse rods of a grey mineral which appears to be troilite and ranges up to 3 mm long. These features are seen in the cut section illustrated in figure 3. The first etch tests produced somewhat blurred results but, on the advice of Mr. E. P. Henderson, of the Smithsonian Institution, Washington, very light etching for 10 seconds with the same reagent was found to produce excellent results, as is seen in the two polished sections illustrated in figures 4 and 5.

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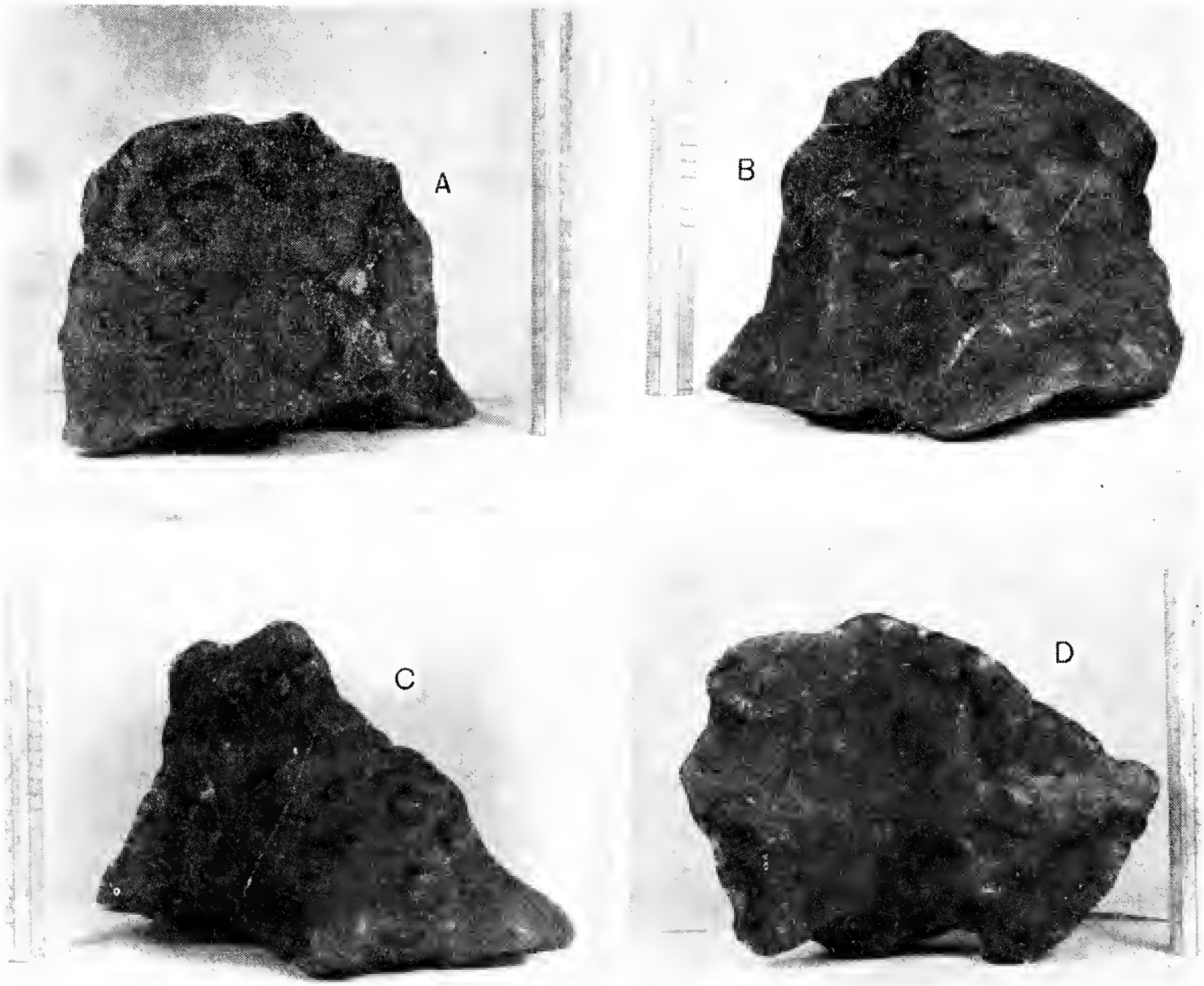

Figure 2.—Western Australian Museum No. 12295. External features of the single mass of the Warburton Range ataxite, showing (A, B, C) regmaglypts on three sides of the roughly triangular tapering cone. The flat sole on which the meteorite is resting in these views is the roughened surface on which the regmaglypts have been partly obscured by weathering (D). The scale in the photographs is 12 inches long.

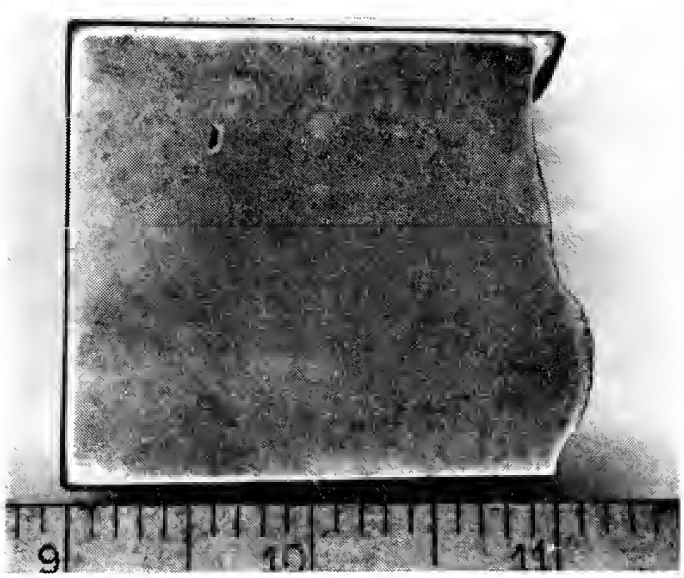

Figure 3.—Cut and polished section of the Warburton Range ataxite showing faint, fine, dark mottled areas and light, inset specks which are larger needles of kamacite. One troilite rod shows, upper left. Scale bar in inches.

Mineragraphy

The etch pattern was studied under reflected light with vertical illumination. The dark mottling evident in figure 3 is seen to be due to areas which are relatively free from minute kamacite needles, and composed entirely of plessite, too fine to be resolved into its components under the optical microscope, and single or clustered kamacite laths larger than those of the fine base network (fig. 4). The plessite mottlings are up to two millimetres in diameter and the largest kamacite laths not more than half a millimetre long. The texture might perhaps be described as microporphyritic or microglomeroporphyritic, but the absence of matrix needles in the vicinity of the "phenocrysts" makes this analogy with textures seen in thin sections of igneous rocks unsatisfactory. The phases present are kamacite (alpha nickel-iron) and taenite (gamma nickel-iron), together with plessite, a "paraeutectoid" composed of very fine intergrowth of these two minerals. The taenite swathes the reflectant kamacite (figs. 4 and 5) in even more reflectant rims, completely or partially surrounding it. The plessite

appears dull grey, finely granular and non-reflectant under high magnification, but although this fine granularity indicates its composite nature it cannot be resolved into distinct mineral grains by the optical microscope. The boundaries between taenite and plessite are indistinct, but, in contrast, those between kamacite and taenite are sharp.

A modal analysis (573 points) gave the following result:

	Volume per cent.
Kamacite	17.0
Taenite	10.3
Plessite	72.7

No troilite was recorded since this is present as very sparse rod-like inclusions (fig. 3). Its identity was confirmed by means of a sulphur print, which also revealed a few minute specks of troilite disseminated in the kamacite-taenite-plessite base. It is possible that a little schreibersite is included with the kamacite.

Chemical composition

Nickel was first determined by J. R. de Laeter, who obtained the surprisingly low value of 10.2 per cent. (McCall 1965). The material was subsequently analysed by one of us (H.B.W.), when the expected higher nickel content compatible with the ataxitic etch pattern was obtained. The later results are:—

	Weight per cent.	
Fe	80.22	
Ni	18.21	19.08
Co	0.87	
Total	99.30	

The remaining 0.70 per cent. could be partly sulphur in the troilite, and minor constituents in trace amounts such as are invariably present in meteoritic iron.

Figure 4.—Photomicrograph of a mottled patch (see fig. 3). An area of plessite includes a single large taenite-swathed kamacite needle, possibly aggregated with one other smaller granule. The more reflectant nature of the swathing taenite is apparent. The groundmass of smaller, but similarly taenite-swathed, kamacite needles is seen on the left-hand side of the photograph. A black speck (lower, centre) could be a silicate inclusion. Scale: x60.

Figure 5.—Photomicrograph of a fine groundmass of kamacite needles, partly or wholly taenite-swathed, and set in less reflectant plessite. The needles of kamacite show an octahedral pattern in their arrangement but there is no suggestion of lamellar structure. The plessite appears finely granular but cannot be resolved into its components. Scale: x60.

Discussion

The bands of kamacite in iron meteorites become progressively narrower as the nickel-cobalt content increases from the values typical of octahedrites (6 per cent. upwards) towards the boundary between octahedrites and nickel-rich ataxites (about 14 per cent.). The Widmanstatten patterns composed of intersecting lamellae are replaced by patterns of discrete kamacite grains, fringed by taenite, within a continuous plessite base. Almost all ataxites possess a microscopically detectable structure of this

sort, even though their name is somewhat misleading, and the criterion of a nickel-rich ataxite is the absence of intersecting lamellae, not a complete lack of etch pattern (Perry 1944, p. 65). The transitional forms of 12-14 per cent. nickel content are difficult to refer to either class of iron meteorite; they may possess the typical ataxitic pattern of discrete kamacite needles, but show, here and there, traces of intersecting lamellae. This transition is also complicated by the fact that there is no exact correlation evident between structural pattern and chemistry (although some of the apparent anomalies may be due to inaccurate analytical techniques). The fact that needles show an octahedral orientation is no indication at all that the meteorite is an octahedrite; all nickel-rich ataxites show this octahedral structure if they show any systematic arrangement of kamacite needles at all (*ibid.*). There is no problem in classifying the Warburton Range iron since it shows no intersecting lamellae at all, and has a nickel-cobalt content well in excess of the transitional value. It is, in fact, the second highest nickel-cobalt content of any Australian meteorite, being only surpassed in this respect by Wedderburn, Victoria (Edwards 1951); for comparison, the compositions of the more nickel-rich iron meteorites from Australia are set out in Table I.

Only some 38 nickel-rich ataxites are now known (Mason 1962, p. 42; Baker *et al.* 1964) and all are finds. No fall of an iron of this type has ever been observed,* but falls of irons are in themselves extremely rare, and the overwhelming majority of irons are octahedrites. Although this type of meteorite is rare, the largest single meteorite mass known is of this type (Hoba, South West Africa; about 60 tons), so it is certain that ataxitic iron occurs in enormous masses and is not just a minor, localised development in the more usual types of meteoritic iron.

The nearest relation amongst Western Australian meteorites is Mount Magnet, which has a transitional structure; areas of intersecting lamellae and areas of discrete needles in plessite like this meteorite.

TABLE 1

Compositions of the more nickel-rich iron meteorites from Australia

	1.	2. (a)	2. (b)	3.	4.	5.
Fe	86·24	85·66	....	82·29	80·22	74·35
Ni	13·43	13·66	14·72	16·90	18·21	23·95
Co	0·16	0·77	0·54	1·09	0·87	0·50

Explanation:

1. Corowa, New South Wales (Baker *et al.* 1964).
2. Mount Magnet, Western Australia (Simpson 1927: Lovering *et al.* 1957)
3. Tawallah Valley, N.S.W. (Hodge-Smith & Edwards 1941).
4. Warburton Range, Western Australia.
5. Wedderburn, Victoria (Edwards 1951).

Analysts: 1—T. H. Donnelly; 2—(a) E. S. Simpson, (b) J. F. Lovering; 3—Chemical Branch, Department of Mines, New South Wales; 4—H. B. Wiik; 5—G. C. Carlos.

All values are weight per cent.

* Note added in proof: A nickel-rich ataxite fell at Muzzaffarpur, India, on 11 April 1964 (Krinov, E. L., 1964, Meteoritical Bulletin No. 32, pp. 1-2).

Structures of the type seen in this new ataxite from Warburton Range are supposed to reflect more rapid phase change in past transformations than has occurred in octahedrites (Uhlig 1954, p. 290). Baker *et al.* (1964, p. 1386) conclude that in view of the absence of definite information concerning pressure conditions operating in the parent body (increased pressure would allow gamma-alpha phase transformations at a lower temperature) little can be done in the way of accurate estimation of the likely range of transformation temperatures applicable to this alloy type, and the rate of growth of the kamacite from taenite is equally difficult to assess.

Further investigations

This material is so fresh that it presents an ideal subject for electron probe and spectrochemical trace element investigations. There is no facility for the former in this State and, while the latter could be attempted, it has been considered better to present this introductory account, leaving the detailed physical and geochemical aspects to be treated separately later.

Acknowledgments

We are indebted to the finders, and to Messrs. J. Harman and W. H. Cleverly of Kalgoorlie for bringing this new meteorite to the notice of the Museum authorities. Assistance was given by Dr. B. H. Mason, of the American Museum of Natural History, New York and Mr. E. P. Henderson of the Smithsonian Institution, Washington. The mass was initially cut by the Commonwealth Steel Corporation, Perth. Mr. J. H. Lord, Director of the Geological Survey of Western Australia, visited the site and supplied an accurate location. The help of Mr. J. R. de Laeter in various ways, and Mr. K. C. Hughes and Mr. W. Smeed in preparing the photographic illustrations and polished sections respectively is also acknowledged.

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3.—The Amphibolurus reticulatus species-group (Lacertilia, Agamidae) in Western Australia

by G. M. Storr*

Manuscript received 16th March, 1965; accepted 22nd June, 1965.

Abstract

The *Amphibolurus reticulatus* species-group consists in Western Australia of four species: *A. pictus* Peters, *A. reticulatus* (Gray), *A. inermis* (De Vis), and *A. clayi* nov. *A. inermis*, which has long been confused with *reticulatus* or regarded as a subspecies of the latter, is shown to be a full species; neither it nor *reticulatus* is divisible into geographical races. In Western Australia, *pictus* breaks up into two races, *salinarum* nov. and *pictus*.

Introduction

This paper is mainly concerned with two closely related and abundant species, *reticulatus* and *inermis*. The other species dealt with, *pictus* and *clayi*, are considerably more distant both from each other and from the first two species. The present species-group is therefore not nearly so homogeneous as the recently investigated *Amphibolurus maculatus* group (Storr 1965).

Failing to distinguish *inermis* from *reticulatus*, many authors have regarded the latter as unusually variable. Actually *reticulatus* undergoes no more individual variation than other species of *Amphibolurus*, and a good deal less geographic variation than most of them, even though it ranges over a quarter of the continent. Its sibling, *A. inermis*, is even less variable throughout its considerably greater area of distribution. Loveridge (1934) was aware that two taxa were involved in the *reticulatus* of authors, but his material was too scanty to reveal their wide sympatry, and he relegated *inermis* to a subspecies of *reticulatus*.

Though described nearly a century ago, *pictus* remains a little known species. Its poor representation in collections is probably due to its specialised habitat preferences. The fourth species, *clayi*, is much rarer still and to my knowledge was not collected until 1931 when Otto Lipfert obtained two on the Canning Stock Route. Another species belonging to this group, *A. decresii* (Duméril & Bibron), is not certainly known from outside South Australia. The MCZ female from Boulder, hesitantly identified by Loveridge as *decresii*, is almost certainly an *A. pictus salinarum*. Its tail and snout-vent length are much the same as in our R 13409, a female possibly collected at the same saltlake.

In the lists of material examined, all specimens with an R number are lodged in the Western Australian Museum; K numbers are of specimens kindly lent by Dr. A. Kluge of the University of Southern California; NTM numbers are of specimens kindly lent by Mr. K. R. Slater of the Animal Industry Branch, Northern Territory Administration, Alice Springs; SAM numbers are of specimens kindly lent by Mr. F. J. Mitchell of the South Australian Museum; and unnumbered specimens prefixed with WHB are of material collected by Mr. W. H. Butler jointly for the Western Australian Museum and the Archbold Collections of the American Museum of Natural History. Unless indicated to the contrary, all localities are in Western Australia; they are listed under Land Divisions in a generally north-south, west-east sequence.

* The Western Australian Museum, Perth, Western Australia.

Diagnosis

The *reticulatus* group consists of stout, terrestrial (usually burrowing) lizards with relatively short head, tail, limbs and digits, a considerably depressed body, and relatively smooth lepidosis. Nuchal scales, except along midline, very small (almost granular). Dorsolateral body scales little larger, but they and dorsals (which increase in size towards midline) may be mixed with large, flat, generally whitish scales arranged in approximately transverse rows. No dorsal crest. Subdigital lamellae very sharply bicarinate. Femoral and preanal pores present in both sexes and juveniles.

Dorsal colour pattern usually consists of either (1) a series of dark blotches along each side of midline, alternating with pale transverse bars or rows of spots; or (2) a dark reticulum. Both kinds of pattern may be present within a single taxon, either as individual, age or sexual variants.

Distribution

The *reticulatus* group is widespread in arid to subhumid habitats of continental Australia. The four species occurring in Western Australia have a collective range throughout the State, except for the far southwest corner where the annual rainfall exceeds 20 inches.

Key to Western Australia taxa

1. a. Nostril on or above swollen rostral ridge	....	2
b. Nostril below acute rostral ridge	....	3
2. a. Femoral pores closely spaced along a straight line parallel and close to outer edge of thigh	....	*reticulatus*
b. Femoral pores widely spaced along a curve that approaches inner edge of thigh	....	*inermis*
3. a. Pores more than 30; nostril circular or broadly elliptical	....	4
b. Pores 10 or fewer; nostril slit-like or narrowly elliptical	....	*clayi*
4. a. No nuchal crest; dorsal scales heterogeneous	....	*pictus salinarum*
b. Low nuchal crest; dorsal scales homogeneous	....	*pictus pictus*

Amphibolurus pictus salinarum subsp. nov.

Holotype.—R 17649, in Western Australian Museum, an adult male collected by G. M. Storr on December 2nd, 1962.

Type locality.—Norseman, Western Australia, in lat. 32° 10′ S and long. 121° 46′ E.

Distribution.—Western Australia south of latitude 27° S and between longitudes 117° and 125° E.

Diagnosis.—Distinguished from nominate *pictus* by its heterogeneous dorsal scales.

Description.—Medium-sized with body and basal half of tail moderately depressed. Head longer, narrower (82% of its length) and less deep (59% of its length) than usual in this group. Relative length of tail exceeded in this group only by nominate *pictus*. Adpressed hindleg reaches to shoulder (females) or tympanum (males). Toes slightly compressed, their outer edge weakly denticulate. Maximum snout-vent length: males 68.5, females 70. Gravid females range from 56.5 to 68. Smallest juvenile 31.

Nostril below moderately acute rostral ridge, a little nearer to orbit than tip of snout, circular or broadly elliptical, and entering forward and downward. Supraciliary ridge acute. Tympanum a little smaller than orbit, its diameter averaging 17% of length of head. Rostral and mental well developed. Upper labials 12-17, smooth, smaller than adjacent facials. A series of enlarged scales extends back from postinferior corner of nasal, below orbit to above ear; at first the scales are flat and smooth but become tectiform under orbit and larger and higher as they curve up towards ear. A loose fold, studded with conical scales 2-3 times as large as neighbouring granules, extends obliquely up from below ear until it joins middle of a similarly scaled dorsolateral fold on neck. No nuchal crest, but a series of subtubercular scales along midline, broader than long, only a little larger than neighbouring scales. No dorsal crest. Strong gular fold curving obliquely back to above shoulder. Frequently a weak pregular fold. No dorsolateral fold on body. Femoral and preanal pores 36-55, slightly raised when gorged, each located in a notch on posterior edge of an enlarged scale and margined by 2-4 small unnotched scales. Subdigital lamellae 21-28 under fourth toe, spinosely bicarinate, the inner series of spines much the higher.

Scales on top of head low, smoothest and largest along midline. Occipital scales smaller and rougher. Scales on nape very small, smooth, subconical. Lateral scales similar, but mixed with scales that are smooth or feebly keeled and 2-3 times as large as ordinary laterals. Dorsal scales increase in size towards midline, flatter and more imbricate than nuchals and laterals, and mixed with smooth non-imbricate scales 2-4 times as large as ordinary dorsals and tending to be arranged in transverse rows. Caudal scales much larger than dorsals, smallest laterally, weakly imbricate, moderately keeled. Scales on dorsal and anteroventral surface of limbs similar to caudals but more strongly imbricate. Scales of under surface of foreleg and ventrolateral scales of outer surface of hindleg much smaller. Gulars small, smooth, weakly imbricate, becoming subgranular towards posterior angle of jaw. Ventrals smooth, imbricate, much larger than gulars and only a little smaller than subcaudals.

All ages and both sexes similarly coloured. Dorsal ground colour greyish to reddish brown. On each side of midline a series of black spots or irregular blotches (occasionally with pale centres) alternating with narrow, yellow or creamy white, finely black-edged transverse bars or rows of elongate spots, each coincident with a row or cluster of enlarged scales. Paravertebral spots and transverse bars on one side of body usually opposite those on other side. Pattern less uniform on lower back, and transverse bars often not collinear with those of other side. Ground colour of lateral and dorsolateral surfaces of body may be masked by intense spotting (the larger spots black, the smaller yellowish white and coincident with enlarged scales). Tail pattern variable and obscure: usually banded with yellowish white and spotted (mainly on sides) with dark brown. Top of head reddish or greyish brown. Sides of head and lower lips pale or greyish brown. Underneath buffy white, except in adult males which have a dark grey patch on chest extending narrowly on to anterior part of abdomen, and a broad median strip on throat from postmentals to pregular fold. Claws colourless or pale brown, becoming darker distally.

Geographical variation.—South from the Murchison to the southern Wheatbelt there is a decrease in the relative length of limbs and tail, an increase in the number of upper labials, and a decrease in the number of subdigital lamellae. Length of appendages thus conform to Allen's rule; and the latitudinal trends in labial and lamellar counts are precisely as in the *maculatus* group.

Eastern Goldfields animals are anomalous in having fewer labials and lamellae than any of the western populations. The specimen from Lake Throssell belongs here rather than with *p. pictus;* its only peculiarity is its low foreleg-hindleg ratio (53%), which however is equalled in a specimen from Lake Varley.

Habitat.—A high proportion of these lizards came from the vicinity of saltlakes, where they excavate their short burrows among samphire growing on marginal flats or on islets in the lakes themselves. In the north and west *salinarum* is probably restricted to this sort of habitat. But in the east where alkaline soils are more general and halophytic shrubbery is widespread (either in pure communities on saltbush plains or as an understory in open woodlands) the species may be found in non-lacustrine habitats and is probably more continuously distributed than in the west.

Paratypes.—North-West Division: R 20537-8 (Lake Anneen, Nannine); R 21292 (Wagga Wagga); R 14879, R 20535-6, R 21293, R 22280-1 (12 mi. SE of Yalgoo). *South-West Division:* R 19015 (Waeel); R 4679 (Kulin); R 18478, R 19240, R 21533 (Lake Varley). *Eastern Division:* R 19026 (Lake Throssell); R 19029 (Cundeelee); R 14231 (Bullock Jinna, 10 mi. S of Cowarna Downs); R 13409a-c (Kalgoorlie district); R 6443 (Kurrawang). *Eucla Division:* R 19016-22 (Norseman district); R 17351,

R 19252-3 (Newman Rock, 27 mi. ESE of Fraser Range); R 283 ("Balladonia"); R 12091-2 (between Israelite Bay and Cape Arid).

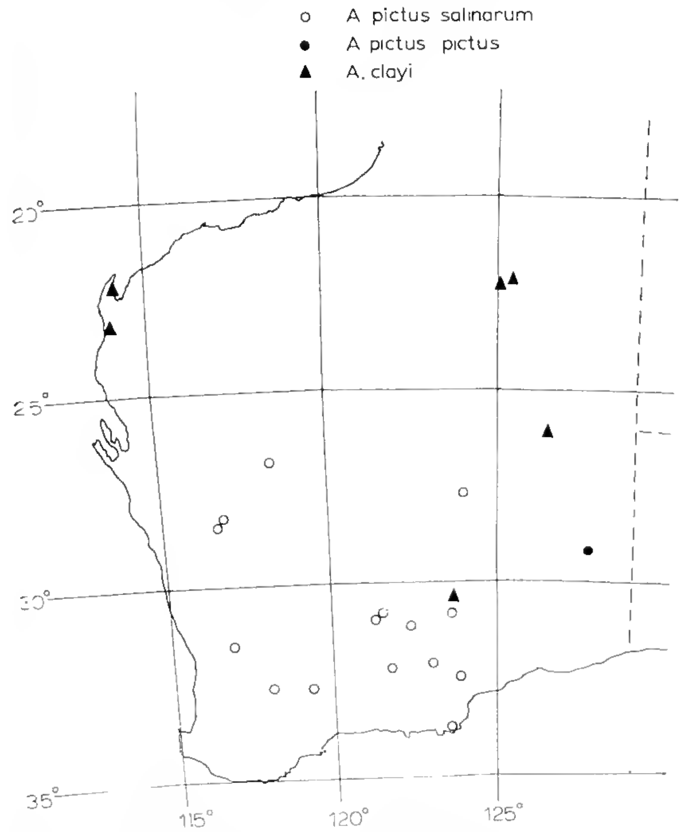

Figure 1.—Map of Western Australia, showing location of specimens of *Amphibolurus pictus salinarum*, *A. p. pictus* and *A. clayi*.

Amphibolurus pictus pictus Peters

Amphibolurus pictus Peters, 1866, Mber. Preuss. Akad. Wiss. **1866**: 88. South Australia (R. Schomburgk).

Distribution.—Far southeast of Western Australia, in the vicinity of the Nullarbor Plain; thence eastwards through South Australia to western Victoria.

Diagnosis.—Distinguished from *p. salinarum* by the absence of enlarged dorsal scales and presence of nuchal crest.

Description.—Generally similar in habitus to *p. salinarum* but has a slightly narrower head (width 80% of length), a longer tail and hindleg, and a lower foreleg-hindleg ratio (50-57 against 53-62%).

Differs in scalation from *salinarum* as follows: scales on top of head higher and rougher; a series of low, laterally compressed spines along midline of nape; ordinary nuchals higher and more acute; dorsals and dorsolaterals increasing in size uniformly towards midline; suborbital series of enlarged scales more strongly tectiform; conical scales on nuchal folds (dorsolateral and subauricular) subspinose; gulars larger (in middle of throat they are not greatly smaller than pectorals, and towards posterior angle of jaw they do not become subgranular but remain imbricate). Upper labials 12-16. Femoral and preanal pores 34-48. Lamellae under fourth toe 22-31.

Dorsal colour pattern much less regular than in *salinarum*, and largely confined to vertebral region. It consists essentially of narrow black bars alternating with transversely elongate, yellow or white blotches. The black bars may have longitudinal branches along midline and along inner edge of dorsolateral stripe of ground colour (brownish or purplish grey). The pale blotches are usually black-edged and straddle midline. Flanks vaguely marbled with dark-grey and sometimes barred with yellow or white. Culmen of claws dark.

Remarks.—The provenance of R 283 (a male *p. pictus*) is doubtful, for another specimen (a female *salinarum*) has the same number, though the register contains only one entry under this number. Specimens R 275-290 were collected in 1914 by W. B. Alexander between Fraser Range and Eucla. The female could well have come from Balladonia; it is similar to females from Newman Rock (48 miles to the northwest). The male may have come from Eucla or Madura, at both of which Alexander collected reptiles. Alternatively Alexander may not have collected the male at all; its discoloration suggests that it has been preserved in formalin, and its metal tag is shiny (as though it were only a few years old); in contrast the female appears never to have been preserved in anything but alcohol, and its metal tag is eroded and tarnished, befitting an age of 50 years. At any rate, too much doubt attaches to these specimens for supposing that *p. pictus* and *salinarum* are sympatric at Balladonia.

Material examined.—Eastern Division: R 19032-3 (Iltoon, near Lake Ell). *Eucla Division:* R 283 ("Balladonia"). *South Australia:* R 24055 (Pidinga, S of Ooldea); SAM 3412 (Coward Springs); SAM 2620-3 (Finniss Spring, 45 mi. NE of Marree); SAM 4991 (Lake Coongee); SAM 4034 (Accalana crossing); SAM 3178 (Yudna Swamp, Moralana); SAM 5628 (Wooltana, Lake Frome); SAM 2782 (Beda Arm, Lake Torrens), SAM 3746 (Renmark); SAM 30 (Bow Hill, River Murray).

Amphibolurus reticulatus (Gray)

Grammatophora reticulata Gray, 1845, Cat. Liz. Brit. Mus., p. 252. Western Australia (J. Gilbert).

Grammatophora laevis Günther, 1867, Ann. Mag. Nat. Hist. (3) **20**: 52. Champion Bay, Western Australia (F. H. Duboulay).

Amphibolurus darlingtoni Loveridge, 1932, Proc. New Engl. Zool. Club **13**: 33. Mullewa, Western Australia (P. J. Darlington).

Distribution.—Western Australia, north to the valley of the Fortescue River and south to the central Wheatbelt (32° 30′ S), thence eastward into South Australia and the extreme south of the Northern Territory.

Diagnosis.—Distinguished from both races of *A. pictus* and from *A. clayi* by the superior position of nostril, and from *A. inermis* by the alignment and number of its femoral pores and by the dark claws and palpebral granules.

Description.—Large and stout with depressed body and short, thick appendages. Snout short and sloping steeply in profile. Width of head

averages 86% of head-length, and depth of head averages 63%. Adpressed hindleg reaches to or a little beyond shoulder. Tail in adult male very thick proximally. Toes short, stout, circular in section. Maximum snout-vent length: males 108 (next largest 98), females 85.5 Gravid females range from 58.5 to 82. Smallest juvenile 27.

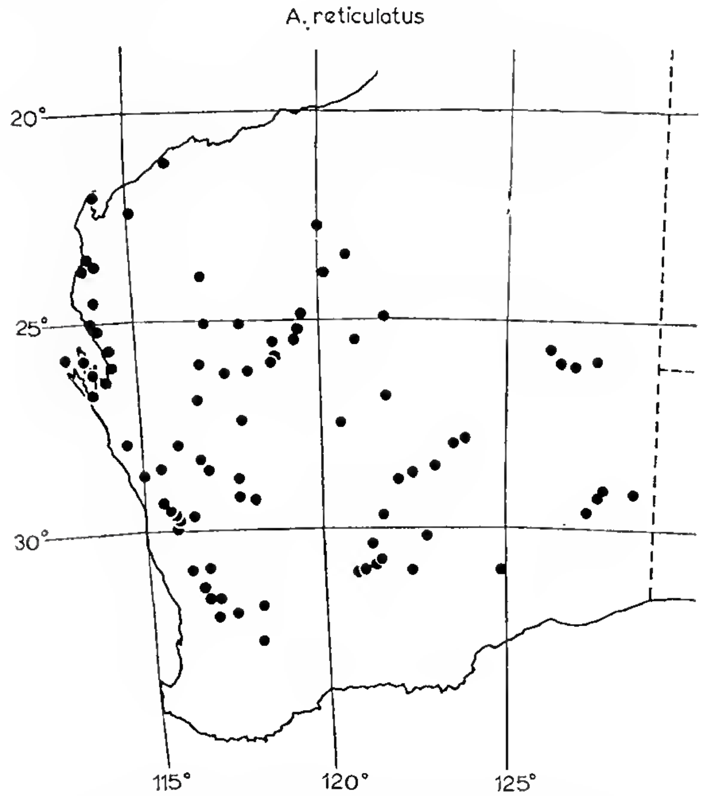

Figure 2.—Map of Western Australia, showing location of specimens of *Amphibolurus reticulatus*.

Nostril on or above swollen rostral ridge, a little nearer to orbit than tip of snout, circular and entering vertically downward. Tympanum considerably smaller than orbit, its diameter averaging 19% of length of head. Rostral and mental well developed. Upper labials 11-19. A series of enlarged tubercular scales increasing in size as they curve up from below orbit to above ear. A series of about five spines extending back from top of ear. A scattered series of about eight spines extending back from gape, below ear aperture to posterior angle of jaw where it may converge with series from above ear. A series of about eight spines arranged in well-spaced groups along dorsolateral edge of neck. (All these spines are poorly developed in juveniles, where they would be better described as tubercles). Low nuchal crest of 6-8 suberect spines scattered serially along midline from occiput to middle of nape. No dorsal crest. Strong gular fold extending obliquely backwards to above shoulder (whence in small juveniles it may continue as a weak dorsolateral fold). Femoral and preanal pores 31-55, each perforating a slightly enlarged scale, arranged close together in a straight line along outer half of thigh, extending almost to knee and narrowly interrupted at midline. Subdigital lamellae sharply bicarinate, 15-27 under fourth toe.

Scales on top of head small (larger than ordinary dorsals but smaller than supracaudals). Occipital and nuchal scales very small. Ordinary dorsal scales small, increasing in size towards midline, smooth or weakly keeled, imbricate, their free edge raised in adults. Enlarged dorsal scales about three times as large as ordinary dorsals, flatter, smooth or weakly keeled, weakly imbricate, and tending to be arranged in transverse rows. Caudal scales large, smallest laterally, imbricate and keeled, the keels aligned longitudinally. Scales on upper surface of limbs similar to but smaller than caudals, becoming smaller and weakly keeled on lower surface of foreleg, and small and smooth on outer ventrolateral surface of hindleg. Gulars and ventrals strongly imbricate, smooth or very feebly keeled.

Dorsal ground colour greyish, yellowish, or reddish brown. Underneath buffy white with or without an obscure grey network on throat (this is darker in juveniles and may extend to abdomen). Dorsal pattern changes, as follows, with age.

Juveniles have a series of black or dark brown spots on each side of midline, the spots on one side usually opposite to but sometimes alternating with those on other side. Between these spots are transverse rows of small whitish spots (each coincident with an enlarged scale), usually collinear with rows on opposite side of back. Tail barred alternately with dark brown and pale brown (dark bars on proximal part of tail may be broken by pale vertebral stripe).

In subadults the whitish transverse bars begin to disappear. A dorsolateral series of grey, elongate, dark-edged spots develops. Anterior caudal bars become obscure as interspaces darken. This is the characteristic colour pattern of adult females, only a few passing into the next stage, which is attained by males well before they are sexually mature.

In adult males the dark paravertebral and pale dorsolateral spots have merged into the dark grey or black network that prevails over head and body. Tail proximally grey or greyish brown, and distally barred with yellowish brown and dark brown. Throat yellowish. In breeding males the pale enclosed dorsal spots become vermilion, and chest and throat reddish orange.

Variation due to age and sex.—We have seen how the dorsal pattern is at first predominantly transverse, then predominantly longitudinal, and finally reticulate. Because males reach this final stage early in their development, and females only acquire it rarely, the species may be regarded as sexually dichromatic.

Throughout growth the relative length of head and limbs decrease with respect to trunk, the rate being faster in females than males. The relative length of tail, however, increases until the snout-vent length is about 50 mm; thereafter it decreases in females, but remains fairly constant in males. All appendages are shorter in females than in males of similar body size.

Geographical variation.—Generally body-size and relative length of appendages decrease with increasing winter cold. Possibly owing to sampling errors, the trends are not smooth. The

Murchison sample (consisting largely of specimens from Mileura) is especially anomalous in its short limbs.

Upper labials average 13.8 in the vicinity of Shark Bay; 14.3 at Exmouth Gulf; 15.7 round the sources of the Fortescue and Gascoyne, and in the Murchison, Wheatbelt and Warburton Range; 16.1 in the Eastern Goldfields; and 16.3 in the Laverton district. Lamellae under fourth toe average 22.2 in the upper Fortescue and Gascoyne, 21.7 at Warburton Range, 21.5 at Exmouth Gulf, 21.3 in the Murchison, 20.6 at Shark Bay, 20.5 at Laverton, 19.6 in the Eastern Goldfields, and 19.0 in the Wheatbelt. Thus, as in the *Amphibolurus maculatus* group (Storr 1965) and the western populations of *A. pictus salinarum* and *A. inermis* (this paper), labial counts tend to increase with decreasing temperature, and lamellar counts to decrease. But the two clines in *reticulatus* operate in somewhat different directions: labials more west-east, lamellae more north-south. Perhaps labials are more affected by winter temperatures, and subdigital lamellae by summer temperatures.

Although regional variation in *reticulatus* is for the most part either clinal or irregular, it may be possible when more material is available from critical areas to group the Western Australian populations into two subspecies: one inhabiting the Indian Ocean drainages, the other the interior drainages. Western animals are larger than eastern, the males averaging 6% and the females 4% longer from snout to vent. Sexual dimorphism is reduced in the east, especially as regards length of limbs. The foreleg is about as long in adult eastern females as in males, and averages about 50% of trunk, compared to 45% in western females. Eastern females are darker and redder than western females, but further east (as exemplified by a specimen from Victory Downs and one from Oodnadatta) the females are larger, paler, and less red. Males from the eastern half of Western Australia are very dark, the black reticulum is thick and so encroaches on the enclosed spots that the dorsum could be described as black, finely spotted with creamy white.

Habitat.—*A. reticulatus* occurs mainly in arid and semiarid, extratropical habitats. Its southern distribution seems to be limited more by humidity than winter cold; for it avoids the west coast south of Geraldton, i.e. as the annual rainfall approaches 20 inches. In the north it barely penetrates the tropics, and its niche is largely taken in the Pilbara region by the abundant *A. caudicinctus*.

A. reticulatus favours heavy, stony soils. Because of this preference, competition is reduced between it and the closely related *A. inermis*. *A. reticulatus* is found under logs and other natural debris, rubbish, fallen fence posts, cowturds and isolated stones and boulders, with or without a short burrow. They also shelter under exfoliating granite and behind the bark of fallen trees. At night they have been occasionally taken asleep in shrubs.

Nomenclature.—Owing to the kind offices of Miss A. G. C. Grandison, Curator of Herpetology in the British Museum (Natural History), I am assured that the name of the foregoing taxon is *Amphibolurus reticulatus* (Gray) and that *Grammatophora laevis* Günther is a synonym of it. Miss Grandison writes (personal communication, July 29, 1964), "While the pores in female specimens in the type series of *G. reticulata* and *G. laevis* are arranged in a slightly wavy line, with each pore usually separated from its fellow, there is no tendency for their alignment to curve over to the inside of the thigh. The condition in the males also resembles more closely condition A than B [referring to my sketches of the femoral pore line in *reticulatus* and *inermis* respectively]. The number of pores in the specimens is as follows:— *G. reticulata* ♂ 20: 20, ♀ 19: 18; *G. laevis* ♂ 20: 18, ♀ 20: 20, ♀ 20: 20 juv. 22: 24."

Material examined.—*North-West Division:* R 13786 (Mardie); R 13316 (Kookhabinna Gorge, Barlee Range); R 18975-6 Koordarrie; R 18977-90 (10 mi. SE of Vlaming Head); K 411 (Kabaura Well); K 414 (Mowboura); R 8161 (Warroora); R 18991-5 (9 mi. SE of Warroora); R 18997-19000 (11 mi. S of Warroora); K 338, 341-3 (12 mi. S of Booloogooroo); R 11257 ("Bernier Island"); R 22400 (10 mi. SE of Carnarvon); R 16944 (23 mi. SSE of Carnarvon); R 21614 (6 mi. N of Wooramel); R 19948 (Yaringa North); R 13167 (Hamelin Pool); R 13127 (Faure Island); R 19001-2, R 19681-2, R 22090, R 22430-1 (Denham); R 18939-40 (Nanga); R 15797, R 18599 (Tamala); R 12456-60 (Dirk Hartog Island); R 10802 (Roy Hill); R 13594 R 18336, R 22497-9 (Jigalong); R 10801 (Mundiwindi); R 19004 (10 mi. SE of Cardawan); R 19006 (25 mi. SE of Three Rivers); R 19007 (12 mi. N of Doolgunna); R 19005 (Peak Hill); R 21291 (5 mi. S of Mt. Clere); R 2699 (Landor); R 914, R 919-22 (Milly Milly); R 15741, R 15746-53, R 15767-9, R 15795-6, R 15798 (Mileura); R 7371-2, R 7376 (Belele); R 19008 (42 mi. N of Meekatharra); R 19009-13 (36 mi. N of Meekatharra); R 738 (Cue); R 15770 (Boolardy); R 8169 (Yuin); R 4945 (Yalgoo); R 53034 (Wadgingarra); R 19014 (9 mi. S of Wydgee); R 12501, R 12508, R 12517 (Paynes Find); R 12516 (Pindabunna). *South-West Division:* R 11113-5, R 19003 (Galena); R 11128 (Eradu); R 4460 (Mullewa—a paratype of *darlingtoni*); R 10203 (Yandanooka); R 11129 (Three Springs); R 21956 (Caron); R 406 (Carnamah); R 22279 (10 mi. S of Carnamah); R 13226 (8 mi. W of Coorow); R 12829 (New Norcia); R 4240 (Wongan Hills); R 22448-9 (Culham); R 3769 (Northam); R 15832 (Meenaar); R 4505 (Beverley); R 2476, R 2480 (Quairading); R 11099 (Bruce Rock); R 4573 (Kulin). *Eastern Division:* R 15845-6 (Weld Spring); R 3894-5 (Windich Spring); R 13701, R 13705 (Mt. Fisher, 110 mi. E of Wiluna); R 12416 (Kathleen Valley); R 19065 (73 mi. E of Cosmo Newberry); R 20694-5 (Beegull Rockhole, S of Lake Throssell); R 20656-8 (White Cliffs); R 1223, R 1230, R 1752, R 22392-3 (Laverton); R 12863 (Mt. Morgans); R 21336 (Ginrock); R 19024-5 (Bardoc); R 12970-2, R 19023 (Bullabulling); R 14126-8 (Dedari); R 4746, R 6436, R 6438-42, R 6444 (Kurrawang); R 4178, R 13422 (Kalgoorlie); R 12991 (Jumnania Rocks); R 14226-30 (Cowarna Downs); R 12973-6 (40 mi. NW of Cundeelee); R 19030 (Naretha); R 19031

(Smith's Station, 90 mi. N of Loongana); R 19243 (Elduna); R 19035-6 (Coolgarbin, west of Lake Ell); R 19034 (Booyanoo, west of Forrest Lakes); R 14630 (40 mi. NW of Warburton Mission); R 14631 (4 mi. N of Warburton Mission); R 15149, R 17740, R 17839, R 19027, R 22101, R 22107, R 22036, R 22205 (Warburton Mission); R 19028 (12 mi. E of Warburton Mission); R 15688-90, R 16522-3 (20 mi. E of Warburton Mission); R 15691-2 (Barrow Range). *Northern Territory:* R 20929 (22 mi. W of Victory Downs). *South Australia:* NTM 1527 (Lambina, Oodnadatta).

Amphibolurus inermis (De Vis)

Grammatophora inermis De Vis, 1888, Proc. Linn. Soc. N.S.W. (2) **1888**: 812. Central Queensland (C. W. de B. Birch).

Amphibolurus reticulatus major Sternfeld, 1919, Senckenbergiana **1**: 78. Hermannsburg, Northern Territory (M. von Leonhardi).

Distribution.—Western Australia north of latitude 29° 30′ S, east through the Northern Territory and northern South Australia to central Queensland.

Diagnosis.—Closely related to *A. reticulatus*, from which it is readily distinguished by the pale claws and by the sparseness and peculiar alignment of the femoral pores.

Description.—Generally similar in habitus to *reticulatus* but larger and having relatively shorter appendages. Adpressed hindleg reaches to shoulder. Base of adult male's tail not so thick as in *reticulatus*. Maximum snout-vent length: males 115, females 98 (next largest 92). Gravid females range from 67 to 89. Smallest juvenile 31.

Generally similar in scalation to *reticulatus*, but differing as follows: spines behind and below ear smaller and arranged more in clusters than series; nuchal crest lower; enlarged dorsal scales less than twice as large as ordinary dorsals; gulars smaller (only half as large as ventrals). Diameter of tympanum averages 21% of head-length. Upper labials 12-21. Lamellae under fourth toe 17-28. Femoral and preanal pores 13-33, each perforating an enlarged scale, widely spaced on a curve that approaches midfront of thigh, and interrupted at midline.

All ages and both sexes similarly coloured. Dorsal ground colour pale orange brown. Head and body covered with dark reddish brown network, finer than in male *reticulatus* and enclosing larger spots, and so disposed as to leave a pale vertebral stripe and occasionally dark paravertebral blotches. A few juveniles have irregularly transverse rows of small white spots. Tail obscurely barred with dark and pale reddish brown, the dark bars usually broken along midline of proximal two-thirds of tail. Palpebral and intraorbital scales much paler than in *reticulatus*, giving the eyes the appearance of being white-spectacled. Culmen of claws unpigmented (they are dark brown in *reticulatus*). Underneath whitish except for throat which in most specimens is faintly reticulated with grey.

Variation due to age and sex.—While there is little sexual or age variation in colour, there is a considerable amount in the relative length of appendages. Length of head, foreleg and hindleg, relative to trunk, decrease throughout growth. Relative length of tail remains fairly constant except for a sudden increase in maturing males. All appendages are much smaller in females than in males of similar body-size.

Geographical variation.—Throughout its wide range this species is remarkably uniform in coloration, proportions and meristics. There are only slight differences in the relative length of appendages, most of which are attributable to Allen's effect. Regional divergences from overall mean relative length of appendages are set out in Table I. Though the regions are largely artefacts of collection, such breakdown of data serves to indicate climatic effects. The tail, especially, decreases in length with decreasing July temperatures (rather than with latitude *per se*). The Warburton Range and Laverton populations are anomalous with respect to length of limbs, and the Exmouth Gulf and MacDonnell Range populations with respect to length of head.

Table II gives regional variation in meristics. In the west, from Kimberley south to the Murchison, upper labials steadily decrease in number, and subdigital lamellae increase. In the interior of the continent no such clines are evident. The high lamellar counts at Warburton Range and Laverton are associated with anomalously long hindleg. Geographical variation in number of pores is everywhere irregular, the highest and

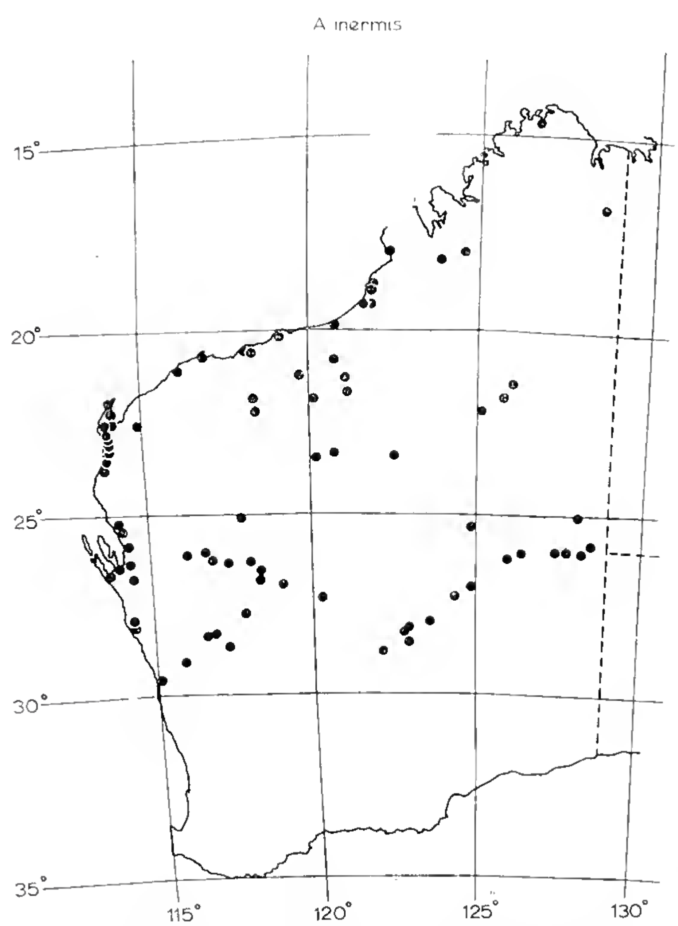

Figure 3.—Map of Western Australia, showing location of specimens of *Amphibolurus inermis*.

TABLE I

Mean regional deviation (%) from overall mean relative length of appendages in adult male Amphibolurus inermis. *The means are of individual deviations from the means for the appropriate snout-vent length class (5 mm intervals). Latitude and temperature data are meaned for locality of specimens (not the region).*

	Number of Specimens	Latitude (°S)	Mean daily temperature July (°F)	Head	Tail	Foreleg	Hindleg
West Kimberley	8	18·8	67·5	+ 5·0	+ 5·2	+ 2·9	+ 2·8
Pilbara	9	21·0	65·2	+ 2·0	+ 2·1	+ 2·1	+ 0·9
Exmouth Gulf	14	22·6	64·1	+ 0·1	+ 4·9	+ 2·4	+ 2·3
Shark Bay	7	27·1	58·9	+ 1·7	+ 1·5	— 2·7	— 1·5
Murchison....	8	26·6	55·9	0	+ 0·2	— 1·3	— 2·8
Warburton Range	13	26·1	54·0	— 2·7	— 2·1	+ 1·4	+ 0·6
Laverton	7	27·9	52·4	— 1·5	— 8·2	— 0·3	— 0·1
MacDonnell Range (N.T.)	14	23·9	53·0	+ 0·3	— 2·8	— 0·8	— 1·6
Oodnadatta (S.A.)	3	27·5	53·3	— 4·0	— 6·3	— 0·7	— 1·2

TABLE II

Mean number of upper labials, lamellae under fourth toe, and femoral plus preanal pores, in various populations of Amphibolurus inermis *(with standard deviations in parentheses).*

	Number of Specimens	Labials	Lamellae	Pores
West Kimberley	21	15·1 (1·2)	21·9 (1·6)	23·1 (2·5)
Pilbara	60	15·5 (1·3)	21·6 (2·1)	21·6 (3·1)
Exmouth Gulf	27	16·1 (1·4)	21·6 (1·8)	20·8 (3·2)
Shark Bay	13	16·5 (1·3)	21·5 (1·9)	22·7 (2·6)
Murchison....	25	15·8 (1·4)	20·7 (1·4)	22·8 (2·3)
Warburton Range	59	16·3 (1·5)	23·1 (1·2)	23·5 (2·5)
Laverton	22	16·6 (1·5)	23·4 (1·7)	25·7 (3·4)
MacDonnell Range (N.T.)	31	15·2 (1·3)	20·0 (1·6)	18·9 (2·7)
Oodnadatta (S.A.)	23	14·9 (1·2)	21·5 (1·6)	20·3 (3·9)

lowest counts (respectively at Laverton and Alice Springs) coming from climatically similar regions.

On the basis of these analyses it is possible to recognise some incipient subspeciation. The western populations (Kimberley to Murchison) are characterised by short limbs (after taking temperature into account); the central populations (Warburton Range to Laverton) by long limbs and high lamellar and pore counts; and the eastern populations (MacDonnell Ranges to Oodnadatta) by short limbs and low pore counts. Except for their more northerly extent in *inermis,* the boundaries between incipient subspecies follow much the same meridians as in *reticulatus*.

Habitat.—In contrast to *reticulatus,* the distribution of *inermis* seems to be affected more by winter cold than humidity. Its southern limits coincide with the 67° F isotherm for mean daily maximum temperature in August.

A. inermis favours sparsely vegetated, sandy to loamy plains. They are seldom found in rocky situations or where the soil is stony. They are adept burrowers, each animal apparently digging several burrows in its home-range. Infrequently a burrow may be located under a rock, sheet of iron, etc., but usually it is dug in a patch of bare soil, where a good view may be had from the burrow-mouth. Where the ground herbage is dense, burrows are apt to be concentrated in the banks of roads or in grader spoil. On little-used roads the lizards often burrow into the "hump" between wheel-tracks. The burrows are 10-20 inches long, and twist sharply down at an average slope of 30°.

A. inermis only climbs (on to termitaria, stones, fence posts etc.) to reach the late afternoon sun. On one occasion two adults were taken from the stomach of a juvenile *Varanus gouldi*.

Material examined.—Kimberley Division: R 13609 (Kalumburu); R 11777 (Lissadell); R 13596 (Paradise); R 19916 (Luluigui); R 13602, R 14090-1 (Broome); R 3446, WHB (8) (La Grange); WHB (2) (Frazier Downs); WHB (2) (Mt. Phire); R 5000, R 15181 (Anna Plains). *North-West Division:* R 1039-48, R 1050, R 1052-64, R 1066-70, R 1073-5, R 1078-80, R 1083, R 1085-6 (Wallal); R 2118-9 (De Grey); R 18876-912 (Mundabullangana); R 17064 (8 mi. E of Mundabullangana); R 17069 (12 mi. E of Mundabullangana); R 17054 (4 mi. S of Nickol Bay); R 18916 (9 mi. NE of Mardie); R 10858 (Hooley); R 13996, R 18914 (Wittenoom); R 5016 (Warrawagine); R 14588 (Braeside); R 14591 (25 mi. S of Braeside); R 18913 (Marble Bar); R 13166 (Nullagine); R 13334-7, R 22495-6 (Jigalong); R 18915 (23 mi. N of Mundiwindi); R 12627 (Yanrey); R 18917 (6 mi. W of Yanrey); R 13126, R 13170-1 (Yardie Creek); R 14182 (Vlaming Head); R 14024 (North-west Cape); R 16997 (6 mi. S of North-west Cape); R 18918-20, K 417, K 420 (10 mi. S of North-west Cape);

TABLE III

Mean snout-vent length, and mean length of appendages relative to trunk, in adults (with standard deviations in parentheses). The figure in parentheses after sample-size is the number of specimens with complete tail.

	Sex	Sample-size	Snout-vent Length	Head	Tail	Foreleg	Hindleg
			(mm.)	%	%	%	%
pictus salinarum	♂	12 (12)	61·0	38·8 (1·6)	223·1 (17·5)	56·5 (2·4)	98·2 (6·5)
	♀	11 (9)	63·0	34·3 (1·1)	190·7 (9·5)	51·5 (2·6)	90·1 (3·6)
pictus pictus	♂	13 (12)	65·0	40·5 (2·5)	265·0 (16·8)	55·0 (2·4)	104·0 (6·8)
reticulatus	♂	32 (25)	89·2	34·4 (2·1)	210·8 (13·4)	48·5 (3·5)	80·5 (6·3)
	♀	30 (25)	75·7	31·7 (2·3)	179·1 (10·7)	46·3 (3·9)	76·0 (5·2)
inermis	♂	86 (76)	101·8	32·7 (2·0)	179·1 (11·8)	47·8 (2·7)	74·3 (3·9)
	♀	38 (33)	85·8	31·1 (1·9)	153·0 (9·5)	47·4 (2·7)	71·6 (3·3)
clayi	♂	6 (6)	48·6	37·6 (1·2)	208·8 (13·2)	54·2 (1·2)	90·2 (3·4)

TABLE IV

Mean (M) number of upper labials, lamellae under fourth toe, and femoral plus preanal pores, with sample-size (N) and standard deviation (S).

	Labials			Lamellae			Pores		
	N	M	S	N	M	S	N	M	S
pictus salinarum	33	14·5	1·5	32	24·1	1·8	25	46·0	4·2
pictus pictus	18	14·4	1·4	16	25·8	2·4	13	42·4	4·1
reticulatus	163	15·3	1·5	164	20·8	2·0	138	39·6	5·0
inermis	296	15·7	1·5	297	21·8	2·0	291	22·1	3·3
clayi	14	16·3	2·0	14	23·4	1·5	8	6·1	1·6

R 11525, R 11529, **K** 459 (Learmonth); R 18921, **K** 361 (6 mi. S of Learmonth); **K** 460-1 (16 mi. SSW of Learmonth); R 18922 (12 mi. S of Exmouth Gulf HS.); R 18929-30 (18 mi. SSW of Bullara); R 16991 (16 mi. NE Ningaloo); R 13595, R 18923 (Point Cloates); R 18925-7 (12 mi. SSE of Ningaloo); R 16976 (19 mi. N of Cardabia); R 16972, R 16975 (14 mi. N of Cardabia); R 18928 (6 mi. N of Cardabia); R 18931-2 (16 mi. N of Warroora); R 8162 (Warroora); R 18924 (10 mi. SE of Gnaraloo); **K** 336 (32 mi. N of Wooramel); R 16939, R 17084 (21 mi. N of Wooramel); R 19947 (Yaringa North); R 13136, R 18935-6, **K** 335 (Overlander); R 18941 (9 mi. W of Hamelin Pool HS.); R 15800 (Tamala); **K** 334 (6 mi. N of Nerren Nerren); R 21289-90 (5 mi. S of Mt. Ciere); R 18937-8 (Byro); R 913, R 915-8 (Milly Milly); R 15762 (Nookawarra); R 15735-40, R 15742, R 15763-5, R 15799 (Mileura); R 7372-6 (Belele); R 19209-10 (Meekatharra); R 18943-4 (Nannine); R 18942 (Moyagee); R 20539 (Wagga Wagga); R 4946 (Yalgoo); R 13963 (Burnerbinmah). *South-West Division:* R 18953 (20 mi. W of Ajana); R 16928 (7 mi. N of Balline); R 16926 (Balline); R 13474 (Lake Arromel); R 2825 (Gutha). *Eastern Division:* R 8714 (Well 42, Canning Stock Route); R 3978 (Well 39. C.S.R.); R 3938-41 (between Wells 31 & 36, C.S.R.); R 8415 (Well 19, C.S.R.); R 15745 (Youno Downs); R 19784-6, **K** 628, **K** 663-4 (Albion Downs); R 17676, R 18945 (Mt. Margaret); R 13109, R 18946-7 (Laverton); R 18948 (25 mi. NE of Laverton); R 20655 (White Cliffs); R 18949 (9 mi. SW of Cosmo Newbery); R 18950-3 (Cosmo Newbery); R 13098 (20 mi. ENE of Yamarna); R 20704 (7 mi. SW of Nullye Rock-hole); R 18955 (18 mi. ENE of Nullye Rock-hole); R 21040 (8 mi. NW of Mt. Beadell); R 18956 (20 mi. SW of Warburton Mission); R 18957 (8 mi. W of Warburton Mission); R 15171 (5 mi. NNW of Warburton Mission); R 14616-26, R 14629, R 15151-4, R 17739, R 17762, R 17783, R 17838. R 18958-67, R 22108, R 22135-64, R 22190, R 22197-8 (Warburton Mission); R 15693-5 (Barrow Range); R 20727-8, R 20989-90 (Cavenagh Range); R 13099, R 20744-5 (Blackstone); R 20971 (Mt. Aloysius); R 20760-1 (Giles). *Northern Territory:* R 21445-52 (7 mi. E of Tennant Creek); NTM 1462 (Haast's Bluff); R 20906-7 (Alice Springs); NTM 1021-35, NTM 1052, NTM 1433-5 (5 mi. S of Alice Springs); NTM 1506-10 (Todd River Station); NTM 1476-83, R 20873 (Hermannsburg); R 20809 (Curtin Spring); R 20800-1 (Mt. Olga); R 13106, R 20772-3 (Petermann Range); R 20943 (15 mi. SW of Mulga Park); R 20940 (Mulga Park); R 20939 (40 mi. E of Mulga Park); R 20913 (Kulgera). *South Australia:* R 20969 (Tomkinson Range); R 20951 (Musgrave Park); NTM 1512-26, NTM 1546-7, NTM 1556-61 (Lambina Station, Oodnadatta).

Amphibolurus clayi sp. nov.

Holotype.—R 14462, in the Western Australian Museum, an adult male collected by G. M. Storr and B. T. Clay on November 1, 1961.

Type locality.—3 miles south of Learmonth, Western Australia, in lat. 22° 16′ S and long. 114° 06′ E.

Distribution.—Only known from a few localities in the Exmouth Gulf region and eastern deserts of Western Australia.

Diagnosis.—Superficially simliar (in habitus and coloration) to juvenile *inermis*, but readily distinguished from that species and other members of the *A. reticulatus* group by its narrow nostrils, uniformly small dorsal scales, few pores, and black gular collar.

Description.—Small with moderately depressed body and relatively short appendages. Width of head averages 81% of its length, and depth 66% of its length. Adpressed hindleg does not quite reach to tympanum. Toes circular in section, their outer edge sharply denticulate. Maximum snout-vent length: males 53.5. Two gravid females measure 48 and 49. Smallest juvenile 24.

Nostril below moderately acute rostral ridge, a little nearer to orbit than tip of snout, slit-like or narrowly elliptical, and entering forward and downwards. Supraciliary ridge acute. Tympanum much smaller than orbit, its diameter averaging 13% of head-length. Rostral broad, as high as or a little higher than adjacent labials. Upper labials 14-21, a little larger than adjacent facials. Mental much smaller than rostral and sometimes undifferentiated from labials. A series of enlarged tubercular scales from back of orbit to top of ear aperture. No nuchal and dorsal crests. Strong gular fold extending obliquely back to above shoulder. No dorsolateral fold. Femoral and preanal pores small, 4-9 (1-2 on each thigh, and 1-3 on each side of preanal region), each located between four unenlarged scales. Subdigital lamellae sharply bicarinate (the inner series of keels much the higher), 21-27 under fourth toe.

Scales on top of head subtubercular, small (but larger than dorsals and nearly as large as supracaudals). Occipital and nuchal scales granular except along midline of neck where they are larger and tubercular. Dorsal scales subgranular, becoming larger and weakly keeled and imbricate along midline. Scales on top of limbs and tail larger, weakly keeled and imbricate. Scales under tail still larger and more strongly keeled and imbricate, their keels aligned longitudinally. Gulars small, smooth, strongly imbricate. Ventrals larger (but not so large as subcaudals), mucronate, strongly imbricate, feebly keeled.

Dorsal ground colour of juveniles yellowish brown. A series of dark brown blotches on each side of pale vertebral stripe (which extends from nape to end of tail), alternating with vaguely defined buffy white transverse bars. A jet black elongate spot on lateral extension of gular fold, which may be joined to its opposite number by a narrow black bar along gular fold. Whitish below.

With maturity the ventral surface becomes buffy white, the dorsal ground colour pale orange-brown, and the dorsal pattern (especially in males) largely absorbed in a dark reddish brown reticulum, which is so disposed as always to leave a pale vertebral stripe and sometimes a discontinuous, ill-defined dorsolateral stripe.

Remarks.—Named after Mr B. T. Clay of the Zoology Department, University of Western Australia, who helped me collect the holotype and much other material in the North-West Division.

This species is possibly not so rare as its belated discovery would suggest, and its scarcity in collections could be due to its unobtrusive behaviour. The two specimens collected by Clay and me in the Exmouth Gulf region were virtually obtained by accident. The holotype was shot on the edge of the road after we stopped to examine a dead *Pseudechis australis*. At the same place we collected *Amphibolurus isolepis* and *A. barbatus*. The other specimen (R 14463) was dug from a burrow in the middle of the road, after we stopped to collect a *Moloch* on a low red sand-dune vegetated with *Triodia* and scattered low shrubs. A *Varanus gouldi* was observed here.

The denticulate toes and narrow nostrils suggest that *clayi* is adapted for living in loose sand. Both features are more strongly developed in the dune-inhabiting iguanid, *Uma*, of western North America.

One of Mr de Graaf's four specimens from the Warburton Mission was identified by aborigines as "mutukala", and another as "tjimpilka". The first of these names is usually applied to *A. inermis* and *A. reticulatus*, and the second to *A. isolepis*. Trouble with this genus is clearly no prerogative of white man.

Paratypes.—North-West Division: R 14463 (5 mi. E of Cardabia). *Eastern Division:* R 3944 (between Wells 31 and 36, Canning Stock Route); R 3968 (Well 37, Canning Stock Route); R 14628, R 21998, R 22006, R 22042 (Warburton Mission); R 12941-5, R 13549 (Queen Victoria Spring).

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4.—Peltacystia gen. nov.: a microfossil of uncertain affinities from the Permian of Western Australia

by B. E. Balme* and K. L. Segroves*

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Abstract

The name *Peltacystia* gen. nov. is proposed as a form genus to accommodate cutinised microfossils of unusual structure, which occur commonly in Upper Permian sediments in the Perth Basin, Western Australia. Three species *P. venosa* sp. nov., *P. calvitium* sp. nov., and *P. monile* sp. nov. are defined. The stratigraphic distribution of the genus is reviewed and its possible affinities and palaeoecological significance are discussed briefly.

Introduction

Since November, 1964, the junior author has been investigating the palynology of Upper Permian sediments occurring in the northern part of the Perth Basin, Western Australia. These deposits have been penetrated by a number of boreholes, particularly in the Wicherina-Eradu district where they contain poor quality, lenticular, coal seams. Because of faulting and the presence of disconformities within the section, the Permian stratigraphy of the northern Perth Basin is difficult to interpret. There is little doubt, on palynological grounds, that the coal-bearing succession in the Eradu district correlates with the Wagina Sandstone in the Irwin River district which has been recently assigned to the Upper Permian (Balme 1964).

Microfloras from Upper Permian sediments in the Perth Basin are in some ways unusual, when compared with those of similar age from other parts of Western Australia. Disaccate pollen are often comparatively rare and some of the common trilete spores have not been recorded elsewhere. A striking feature too, of many assemblages, especially those from coals, is their high content of cutinised microfossils which lack the typical morphographic characters of spores and pollen grains of vascular plants. Most specimens in this category can be accommodated in existing form genera, but some of the more distinctive and common types do not appear to have been yet described. The purpose of this account is to define and illustrate three species which have been previously noted in Permian sediments from other sedimentary basins, but never in sufficient numbers to enable their structure and variation to be confidently interpreted.

Sources of samples

Samples containing one or more of the species under discussion were obtained from boreholes and shafts sunk in the northern Perth Basin by various authorities. Type specimens of all three species were taken from a single sample of coal from a seam encountered in a borehole which penetrated the Wagina Sandstone near Woolaga Creek in the Irwin River district. Specimens used for additional illustration were obtained from two samples recovered from bores in the Eradu-Wicherina district. Details of these three samples are as follows:

Sample No. 49741: Inferior canneloid coal at 91-95 feet, U.W.A. 4 (Woolaga Creek) Borehole (29° 10′ 36″ S., 115° 40′ 24″ E.), Irwin River District, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Sample No. 43290: Grey siltstone at 367-373 feet, Public Works Department Bore X49 (28° 41′ 9″ S., 114° 59′ 38″ E.), Wicherina District, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Sample No. 43283: Coal at 135-157 feet, Eradu Coal Bore No. 5 (28° 41′ 34″ S., 115° 2′ 0″ E.), Eradu District, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Additional records of occurrences of the species described are listed in a subsequent section of the paper.

Storage of specimens

Types and illustrated specimens are mounted singly in glycerin jelly and sealed with beeswax and clear varnish. They are stored in the museum of the Department of Geology, University of Western Australia, and specimen numbers given in the text refer to the catalogue of collections of that repository.

Techniques

Clastic sediments were prepared for examination by boiling a few grams of sample in 50% hydrofluoric acid and treating the organic residue with Schultze solution followed by weak alkali. Coals were oxidised with concentrated nitric acid and the alkali soluble fraction subsequently removed with 5% sodium hydroxide.

Systematic descriptions

Genus **Peltacystia** gen. nov.

Type species.—Peltacystia venosa sp. nov., Wagina Sandstone, Perth Basin, Western Australia. Upper Permian.

Diagnosis.—Acid insoluble microfossils of uncertain function. Body spheroidal or oblate spheroidal with a sharply defined equatorial line of weakness along which the body tends to split into two symmetrical halves. Each hemisphere divided into a polar and equatorial zone by a circumpolar ridge, or ring of sculptural processes, which encircles the body about half way between the pole and the equator.

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Additional circumpolar ridges or rings of processes may be present in the polar zones and the remainder of the body wall may be laevigate or variously sculptured.

Remarks and comparisons.—*Peltacystia* belongs to that group of form genera which is primarily characterised by a tendency to rupture equatorially along a sharply defined line of dehiscence. In *Peltacystia* rupture is normally complete and detached halves are much more common than intact specimens. *Schizosporis* Cookson and Dettmann differs mainly in its lack of circumpolar ornament and in *Schizocystia* Cookson and Eisenack the shell tends to be quadrilateral with concave sides. *Lecaniella* Cookson and Eisenack, from the Cretaceous of Western Australia may well be a closely related form. *Lecaniella margostriata* Cookson and Eisenack resembles in some ways the separated hemispheres of *Peltacystia venosa* sp. nov. and Cookson and Eisenack (1962) suggested the possibility that *Lecaniella* represented the ruptured halves of originally sub-spheroidal bodies. They were, however, unable to confirm this by finding specimens which were certainly intact. If *Lecaniella* is eventually proved to have arisen by equatorial rupture it is distinguishable from *Peltacystia* in its lack of a well-defined circumpolar ridge. The illustrations given by Jansenius (1962, plate 16, figures 2-4) of *Grebespora concentrica* Jansonius are faintly reminiscent of some ruptured specimens of *Peltacystia*, but in his diagnosis Jansonius makes it clear that his species is a flattened hollow body bearing a concentric marginal fold. A form illustrated by Alpern (1959, plate 17, figure 432) as *Nuskoisporites* ?sp. may be assignable to *Peltacystia*. Alpern's specimen came from the Westphalian of Lorraine and may, therefore, be a much older record of the genus than any reported in the present account.

Derivatio nominis.—Greek πελτη a small shield, from the shape of the ruptured halves.

Affinities.—On morphological analogy with living forms the most obvious inference is that the various species of *Peltacystia* represent unicellular members of the Chlorococcales, although there seems no possibility of demonstrating this. The mode of rupture resembles that of modern artificial genera such as *Desmatractum* and *Octogoniella* and the sculptural pattern of *Peltacystia venosa* sp. nov. recalls the surface ornament of *Trochischia*. An algal origin has been suggested by several authors (e.g. Cookson and Eisenack 1962, Churchill 1960) for other form genera with a similar dehiscence mechanism to *Peltacystia*, although the comparisons have been quite properly guarded.

That *Peltacystia* is not the spore or pollen grain of a vascular plant is further suggested by two observations during the present investigation. Firstly, its wall differs chemically from that of spores and pollen grains and is more resistant to the action of Schultze solution and alkali. This may be demonstrated by oxidising slightly weathered sediments until the spores and pollen grains are destroyed, or swollen almost beyond recognition. Specimens of *Peltacystia* (and, incidentally, various other microfossils of suspected algal origin) are, however, apparently unaffected. Secondly, the occurrence and associations of *Peltacystia* hint at a nonvascular origin. Although it has been found in marine sediments it has so far only been recorded in high concentrations from coals and clastic sediments closely associated with coals. Where it occurs abundantly *Peltacystia* is invariably accompanied by large numbers of other microfossils of probable non-vascular origin. Such microfossils are assignable to, among others, the form genera *Pilasporites* Balme and Hennelly, *Tetraporina* (Naumova), *Schizosporis* Cookson and Dettmann and *Circulisporites* de Jersey. Microscopic algal colonies resembling *Botryococcus* are also associated with *Peltacystia* in some assemblages. On the available evidence, therefore, large numbers of *Peltacystia* may be taken to characterise continental, fresh or brackish water, sediments. A more reliable assessment of its palaeoecological significance may be possible when detailed palynological studies of Permian sediments in the Perth Basin have been completed.

Known stratigraphic distribution.—Artinskian and Upper Permian. Specimens have only rarely been found in sediments older than Upper Permian, but in view of the apparent facies dependence of *Peltacystia*, any firm conclusions concerning its biostratigraphic significance would be premature.

Peltacystia venosa sp. nov.

Figure 1, a-b. Figure 2, a-f. Figure 3, f-k.

Holotype.—53992.

Paratypes.—53993, 53994, 53995.

Diagnosis.—Body sub-spheroidal, splitting by equatorial rupture into two symmetrical halves. Intact specimens rare. Wall 1-2μ thick. Each hemisphere divided into a polar and equatorial zone by a low, narrow, circumpolar ridge bearing papillate or capitate processes 1-2μ in basal diameter and 3-5μ long. Additional circumpolar ridges or rings of processes may be present in the polar zone. Remainder of surface reticulate with low muri about 1μ wide which basically radiate from the polar area, but form a complex pattern by dichotomy and anastomosis. Muri terminate by merging into the circumpolar processes. Equatorial zone bearing radiating muri which arise in the processes of the circumpolar ridge, sometimes dichotomise and terminate with a slight thickening at the line of equatorial rupture. Periphery of ruptured specimens notched.

Dimensions.—Equatorial diameter (40 specimens) 35-65μ (mean 45μ).

Descriptions.—Holotype 53992: intact specimen preserved in oblique view; equatorial diameter 48μ, polar diameter about 46μ. Paratype 53993: ruptured specimen in equatorial view; equatorial diameter 49μ, estimated polar diameter 48μ. Paratype 53994: ruptured specimen in polar view, equatorial diameter 43μ. Paratype 53995: intact specimen in oblique view, equatorial diameter 49μ, estimated polar diameter 46μ.

Locus typicus.—Coal at 91-95 feet, U.W.A. 4 (Woolaga Creek) Borehole, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Derivatio nominis.—Latin *venosus* = veined.

Remarks and comparisons.—*Peltacystia venosa* is the most common and widely distributed of the three species of the genus so far recognised. It is known from Upper Permian sediments in the Perth, Canning and Collie-Muja Basins and is easily recognised even when poorly preserved. It is distinguished from other species of *Peltacystia* by the reticulate sculpture of its polar zones.

Known stratigraphic range.—Upper Permian.

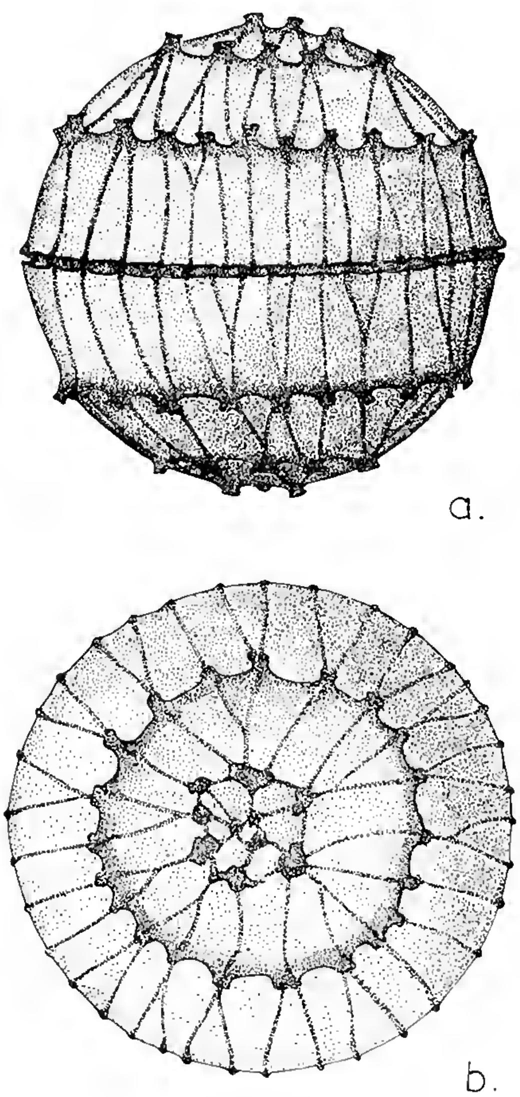

Figure 1.—*Peltacystia venosa* Balme and Segroves. Reconstruction of intact specimen. a. Equatorial view. b. Polar view. X1000.

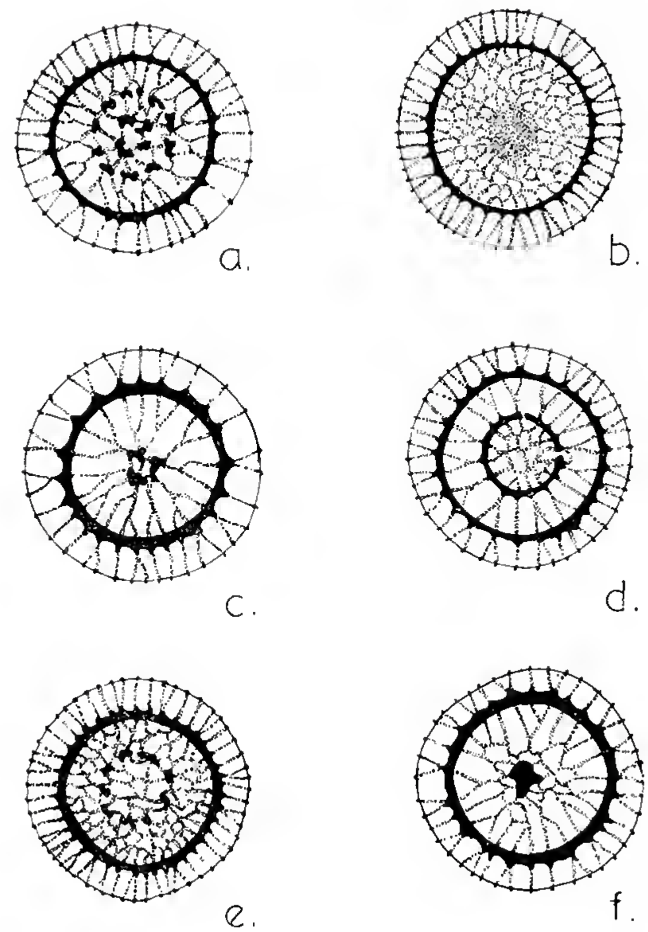

Figure 2.—*Peltacystia venosa* Balme and Segroves. a-f. Polar views showing variations in sculptural patterns on six selected specimens. X500.

Peltacystia monile sp. nov.

Figure 4b. Figure 3, a-e.

Holotype.—53996.

Paratypes.—53997, 53998.

Diagnosis.—Body oblate spheroidal, splitting by equatorial rupture into two symmetrical halves. Detached halves more common than intact specimens. Wall about 1μ thick. Each hemisphere bearing a circumpolar ring of small verrucate or papillate processes lying about half way between the pole and equator. Individual processes 1-2μ in basal diameter, 1-2μ high and less than 1μ apart. Bases of processes joined in some specimens to form a continuous subcristate ridge. Scattered processes sometimes present in the polar zone. Remainder of surface laevigate or faintly punctate, equatorial periphery of ruptured specimens finely notched.

Dimensions.—Equatorial diameter (20 specimens) 28-40μ (mean 33μ).

Descriptions.—Holotype: intact specimen preserved in oblique view, equatorial diameter 34μ, polar diameter about 31μ. Paratypes: separated

Figure 3.—Opposite.

Figure 3.—All magnifications X750. a. *Peltacystia monile* Balme and Segroves. 53999. Intact specimen in oblique view. b. *P. monile.* Holotype 53996. Intact specimen oblique view. c. *P. monile.* 54000. Ruptured specimen in polar view. d. *P. monile.* Paratype 53997. Ruptured specimen in polar view. e. *P. monile.* Paratype 53998. Ruptured specimen in polar view. f. *Peltacystia venosa* Balme and Segroves. Ruptured specimen in polar view. g. *P. venosa.* 54005. Ruptured specimen in polar view. h. *P. venosa.* Paratype 53994. Ruptured specimen in polar view. i. *P. venosa.* Paratype 53993. Ruptured specimen in equatorial view. j. *P. venosa.* Paratype 53995. Intact specimen in oblique view. k. *P. venosa.* Holotype 53992. Intact specimen in oblique view. l. *Peltacystia calvitium* Balme and Segroves. Intact specimen in oblique view. m. *P. calvitium.* Paratype. 54002. Intact specimen in polar view. n. *P. calvitium.* Holotype 54001. Intact specimen in equatorial view. o. *P. calvitium.* Paratype 54003. Intact specimen in equatorial view.

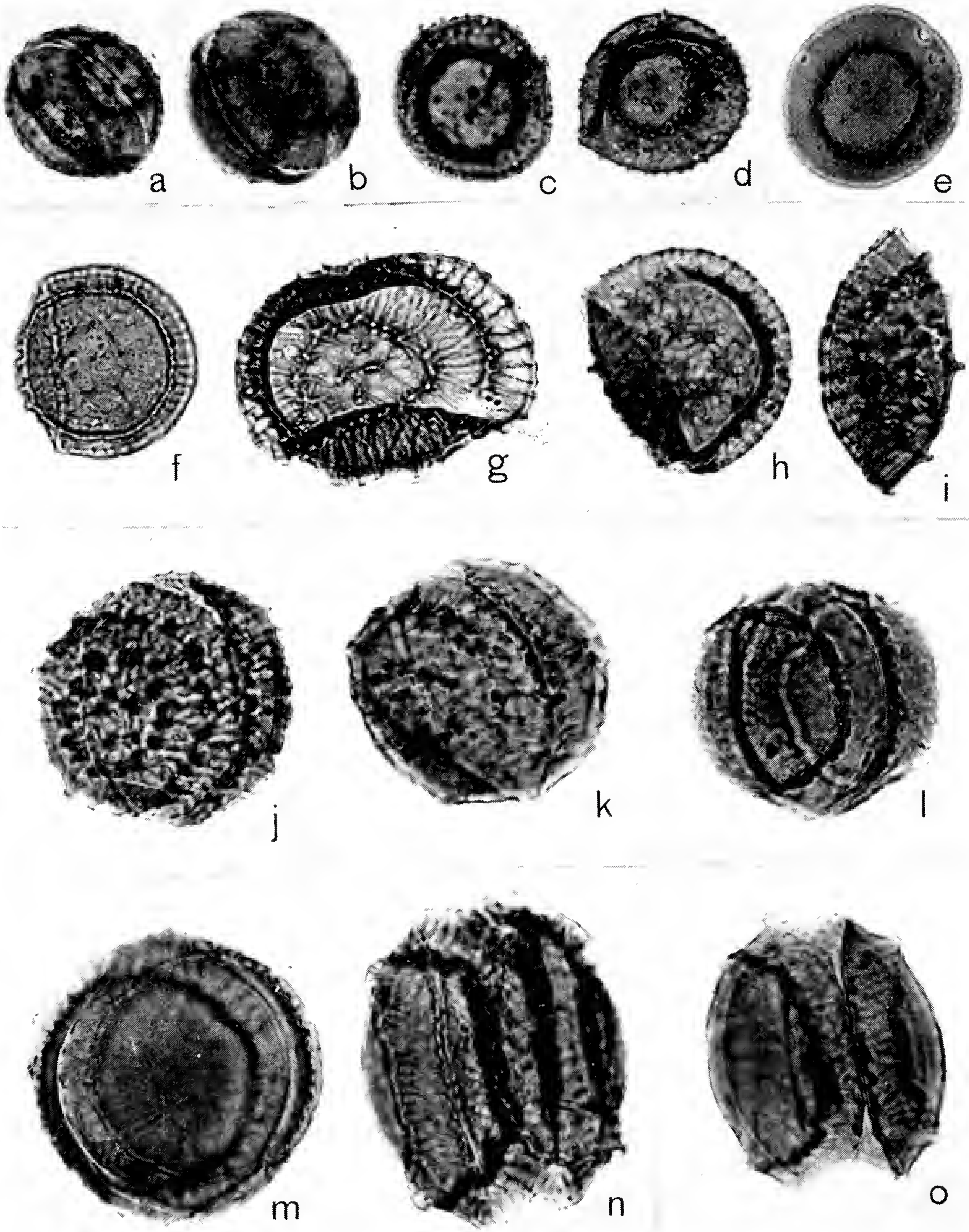

Figure 3.

halves in polar view, both with about 5 small sculptural processes scattered in the polar area. In paratype 53998 the sculptural elements of the circumpolar ring are more numerous than in 53997.

Locus typicus.—Coal at 91-95 feet, U.W.A. 4 (Woolaga Creek) Borehole, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Derivatio nominis.—Latin *monile* = a necklace.

Remarks and Comparisons.—*Peltacystia monile* has been recorded from the Perth, Collie-Muja and Canning Basins, but may have been overlooked in material from other areas. It is smaller than *peltacystia venosa* and lacks reticulate sculpture.

Known stratigraphic range.—Upper Permian.

Peltacystia calvitium sp. nov.

Figure 4a. Figure 3, 1-o.

Holotype.—54001.

Paratypes.—54002, 54003.

Diagnosis.—Body oblate spheroidal splitting by equatorial rupture into two symmetrical halves. Intact specimens more common than ruptured, at least in the type material. Wall 2-4μ thick, slightly thicker in the polar than in the equatorial zones. Each hemisphere bearing a clearly defined circumpolar ridge 2-5μ high encircling the body about half way between the pole and the equator. Top of ridge weakly undulate and sometimes bearing grana, but without heavy processes. Polar zones laevigate or faintly punctate. Equatorial zone with poorly defined, dichotomising, striae which arise on the circumpolar ridge and terminate at the line of equatorial rupture. Equatorial periphery weakly notched in ruptured specimens.

Dimensions.—Equatorial diameter (20 specimens) 44-59μ (mean 50μ).

Descriptions.—Holotype: intact specimen preserved in equatorial view, equatorial diameter 52μ, polar diameter 44μ, wall thickness 4μ in polar region. Striae of equatorial zone clearly defined. Paratype 54002: intact specimen in polar view, equatorial diameter 58μ. Paratype 54003: intact specimen in equatorial view, equatorial diameter 53μ, polar diameter 44μ.

Locus typicus.—Coal at 91-95 feet, U.W.A. 4 (Woolaga Creek) Borehole, Perth Basin, Western Australia. Wagina Sandstone, Upper Permian.

Derivatio nominis.—Latin *calvitium* = a bald head.

Remarks and comparisons.—*Peltacystia calvitium* was abundant in the type material but has not been frequently encountered elsewhere. Rare specimens of *Peltacystia* occurring in Artinskian sediments from the Canning Basin are similar to *P. calvitium*, but they have not been studied in enough detail to be sure of their identity.

Peltacystia calvitium differs from *P. venosa* in its well-defined circumpolar ridge which lacks heavy additional processes and in the absence of sculpture in the polar zone. *P. monile* is smaller than *P. calvitium* and lacks the pronounced circumpolar ridge.

Known stratigraphic range.—?Artinskian—Upper Permian.

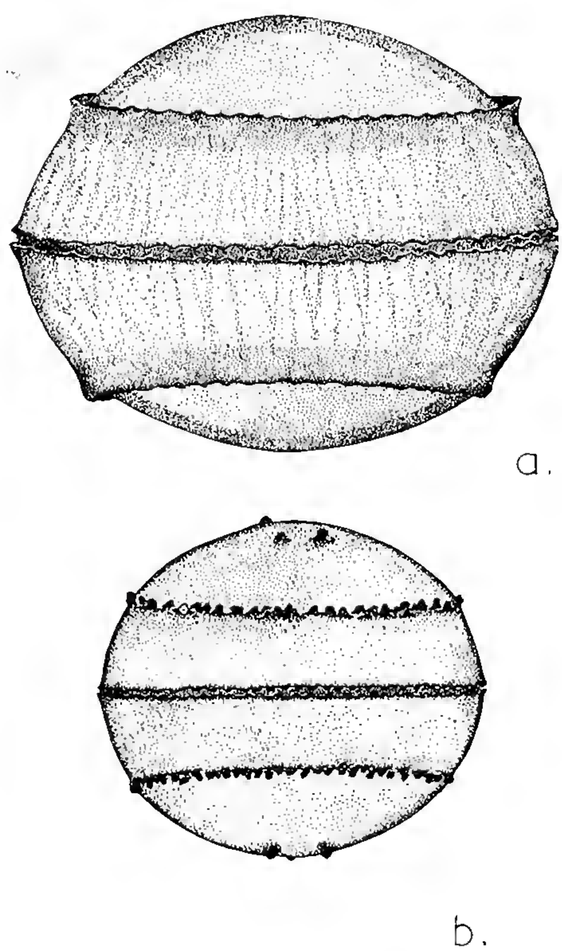

Figure 4.—a, *Peltacystia calvitium* Balme and Segroves. Reconstruction of intact specimen in equatorial view. b. *Peltacystia monile* Balme and Segroves. Reconstruction of intact specimen in equatorial view. Both reconstructions X 1000.

Distribution

Apart from the type locality the various species of *Peltacystia* have been recorded from a number of other localities in Western Australia, especially in bores in the Wicherina-Eradu area. These bores were sunk by various companies engaged in coal exploration or by the Public Works Department of Western Australia. as part of its hydrological programme. Locations of some of the bores listed from the Perth Basin may be found in the publication by Johnson, De la Hunty and Gleeson (1954) and those of the remainder in the unpublished thesis by Olgers (1959) which is lodged in the Library of the University of Western Australia. With the exception of the Noonkanbah Formation, the formations from which the samples listed below were obtained are all considered to be Upper Permian.

Perth Basin

Peltacystia venosa.—Eradu Coal Bore No. 1. 640 feet; Eradu Coal Bore No. 5, 135-157 feet; Eradu Coal Bore No. 8. 172-211 feet; Eradu

Coal Shaft, 144-161 feet; P.W.D. Bore X48 Wicherina, 397-403 feet; P.W.D. Bore X49 Wicherina, 200-225 feet, 367-373 feet.

Peltacystia monile.—Eradu Coal Bore No. 8, 172-211 feet; Eradu Coal Shaft, 144-161 feet; P.W.D. Bore No. 48 Wicherina, 397-403 feet; P.W.D. Bore X49 Wicherina, 367-373 feet.

Peltacystia calvitium.—Eradu Coal Bore No. 1, 640 feet; P.W.D. Bore X48 Wicherina, 256-258 feet, 391-397 feet, 397-403 feet, P.W.D. Bore X49 Wicherina, 200-225 feet.

Collie-Muja Basin

Peltacystia venosa.—Cardiff Main Seam, Cardiff Colliery; Griffen Seam, Griffen Colliery; Muja No. 1 Bore, 50 feet.

Peltacystia monile.—Cardiff Main Seam, Cardiff Colliery; Griffen Seam, Griffen Colliery.

Peltacystia calvitium.—Griffen Seam, Griffen Colliery.

Canning Basin

Peltacystia venosa and *P. monile* have been recorded from the Liveringa Formation at several localities, but neither species is common in any material so far examined. A form resembling *P. calvitium* occurs rarely in sediments assigned to the Artinskian Noonkanbah Formation in B.M.R. 1 (Jurgurra Creek) Bore.

Acknowledgments

We are indebted to the Director of the Geological Survey of Western Australia (Mr. J. H. Lord) for supplying samples from the Eradu Coal Bores and to officers of the Public Works Department who co-operated in the collection of material from water borings in the Wicherina district.

Photomicrographs are the work of Mr. K. C. Hughes of the Department of Geology.

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Vol. 49 Part 2

5.—Fire in the jarrah forest environment

Presidential Address, 1965

by W. R. Wallace*

Delivered 19 July, 1965

Abstract

The fire history of he forest before and after colonisation is discussed and the adaption of the species to a fire climate emphasised. Type and severity of fires in virgin and cut-over forests are compared and the problems associated with fire protection are noted. The failure of a policy of complete protection from fire after 30 years, despite early success, is pointed out, and the problems associated with a sudden change to broadcast controlled burning are outlined.

Present methods of burning as dictated by research are defined and the prospect of successful rotational burning over the whole forest area is indicated.

Introduction

The jarrah (*Eucalyptus marginata* Sm.) forest is indigenous to the south-west corner of Western Australia, where it originally covered an area of some 13,000,000 acres, of which more than half has been alienated for other purposes—mainly agricultural. Four million acres of the better quality forest has been permanently dedicated as State Forest, under the Forests Act 1918-54, and the remaining area of 1,500,000 acres is classified as vacant Crown Land.

The main forest belt occupies the undulating plateau of the Darling Range at altitudes varying from 400 to 1600 ft. It extends from just north of Perth to merge with the karri (*E. diversicolor* F.v.M.) forest 200 miles to the south. Varying in width from 20 to 35 miles, its range is limited in the east by the 25-inch isohyet and in the west by the Darling Scarp; some outliers occur on the coastal plain. The species reaches its optimum development on the deep gravels on the middle and lower slopes of the laterite-capped ridges of the Darling Range. The tree is a grey stringy bark, which may reach a maximum of 6 feet in diameter and 140 feet total height.

Gardner (1942) describes the forest as a true sclerophyllous formation and remarks on the paucity of other tree species within the forest proper. Marri (*E. calophylla* R.Br.) is a minor associate and Western Australian blackbutt (*E. patens* Benth.) occurs on the moister soils, with bullich (*E. megacarpa* F.v.M.) and flooded gum (*E. rudis* Endl.) along some of the watercourses. Intrusions of wandoo (*E. redunca* Schauer *var. elata* Benth.) occur on the eastern fringe.

The main understorey trees are *Banksia grandis* Wield. and sheoak (*Casuarina fraseriana* Miq.f.) with a ground cover of relatively harsh-leaved shrubs. The ubiquitous and highly inflammable blackboy (*Xanthorrhoea preissii* Endl.) and the zamia palm (*Macrozamia reidlei* Gand.) occur throughout.

The climate of the region is typically Mediterranean with a well defined winter rainfall and near drought in the summer months. Total annual rainfall varies from 30 to 50 inches in the main forest belt with minimum falls in January and February when rainless periods of up to 30 to 40 days may be experienced. The ground temperature may reach as low as 25°F. in winter and screen temperatures exceed 100°F. on a few days each summer. A detailed climatic analysis covering the subject area has been published recently by the Bureau of Meteorology (Australia 1965). Because of this weather situation the forest is susceptible to fire for six months each year, and when subnormal winter rainfall is experienced it is possible to have a free running fire in this forest in every month of the year.

Natural resistance of the species to fire

Jarrah, recognised as one of the most fire resistant of the eucalypts, has had a fire history over perhaps thousands of years and the species has built up various forms of resistance to this phenomenon while reaching the status of a climax type.

Primarily, some trees in the forest carry seed each year, with particularly heavy seeding at irregular intervals. Light fires assist in the opening of the seed capsule and the seed then falls on the relatively weed free surface of a fertile ashbed. The young seedling develops a ligno-tuber which has been cited by Jacobs (1955), Harris (1955), and Loneragan (1962) as an outstanding adaption to the fire habitat.

*Forests Department, Perth

Under natural forest conditions the young jarrah sapling does not spring immediately from the seedling but exists as a semi-dormant procumbent shrub until the ligno-tuber has reached a diameter of 3-4 inches: usually a period cf 10-20 years or more. At this stage the stimulation of an opening of the canopy, removal of scrub competition and/or fire enables the advance growth to at last send up a single dynamic shoot from which the young tree develops.

As a further protective measure, jarrah develops a heavy bark up to 1½ inches thick in the mature tree. The bark is stringy in texture and finely fibrous on the outer surface when protected from fire. Light fires burn the surface bark only but with fires of greater intensity, the whole of the dry outer bark is consumed and this contributes markedly to the total heat production and, also, to the extension of a fire by throwing burning flakes of bark ahead to form "spot fires".

Recent work (Peet 1965) has shown that the oven-dry weight on the tree boles is of the order of 6 tons per per acre of which 4 tons is the dry outer bark. This is equivalent to a five year accumulation of litter on the forest floor (Hatch 1955) and is a significant fuel factor in severe fires.

Exfoliation of the outer layers of bark, blackened after a fire, takes 15-20 years and it is suggested that this period is required for equilibrium of bark production and normal bark shed and for maximum bark thickeness.

The species has developed a remarkable ability to coppice from dormant buds in the live bark and even mature trees, some hundreds of years old, may send up vigorous shoots from the stump after the tree has been felled. Similarly, dormant buds in the trunk and crown produce vigorous epicormic shoots after a severe fire and will rapidly replace the crown. Even when the crown is killed it is still possible for the tree to survive at least over a period of years, if sufficient numbers of epicormic shoots develop along the bole.

With these adaptations for survival, jarrah has developed the means to withstand all but the most severe fires.

Pre-colonisation era

As early as the 17th century the logs of such navigators as Pelsart, Vlaming, Jonk and Volkerfen made reference to smoke and fires on the mainland of this country. From these reports it must be assumed that the aborigines of this State, in common with those of eastern Australia (King 1963), were well acquainted with fire. Their nomadic habit of moving in small family groups from place to place in search of food suggests that at least one, and probably more fire-sticks were carried by each party. Evidence also points to a habit of burning patches of the country to provide more succulent growth as a lure for game, and King states that they used fire as a barrier to the movements of animals and to assist in their capture. Add to these possible uses of fire the number of cooking fires which must have been burning each day, in and around the forest, and there is little doubt that there were many sources of wildfire available at all times. There is no evidence to show that the natives made any particular attempts to confine their fires or to suppress any accidental outbreaks and it may be assumed that fires, once started, continued to burn as long as fuel was available and weather favourable.

Summer lightning is responsible for a number of uncontrolled fires each year and it must be accepted that this source of fire was also present before the arrival of the white man.

The vast extent of the original virgin forest with its carpet of leaf litter and low shrubs (Fig. 1) presented an ideal fuel bed through which a summer fire could creep for weeks on end, unhindered by anything but a rare shower or an occasional moist gully. With the possibility of a number of fires of this type occurring in the forest area at the same time, it is not unreasonable to assume that the forest was completely burnt through every 2-4 years. Even as late as 1925 the writer was able to observe three fires of this nature in unmanaged virgin forest east of Jarrahdale. These fires were alight in December and continued to burn until the following March, increasing in intensity as hot weather developed and waning to a faint smoke on the cooler days, until finally extinguished by steady rain. In 1930-31 a fire which started in early December moved steadily through the virgin forest, covering a distance of some 15 miles in 3 months. There was virtually no damage to the forest crop from this quietly moving low-intensity fire. This is a direct contrast to the Dwellingup fire in 1961, which covered 15 miles in 15 hours, causing complete defoliation and serious material loss.

Descriptions of the forest by the early settlers confirmed the opinion that the jarrah forests had been the subject of frequent light fires over many centuries, and that the species had so developed that it suffered the minimum damage from this treatment. They found a forest of massive, largely over-mature trees with 30-60 feet boles towering to 100-140 feet in height, with few understorey trees and a meagre cover of woody shrubs over a continuous carpet of leaves and twigs 0-4 years of age—a forest burnt every few years by relatively light fires burning mainly in the months of mid-summer. Flames from these light fires could have been no more than 1-3 feet high, in the limited fuel available, and caused little damage to the trunks of the trees and even less to the crowns towering high above them.

The post-colonisation era

One of the main reasons for the colonisation of Western Australia was the vast expanse of its forests and the great demand for suitable timber for shipbuilding by the Royal Navy following the decimation of its oak forests over previous centuries. Utilisation of this forest wealth commenced immediately after the arrival of the first settlers and one of the earliest export records (1836) of the new colony includes 10,000 cubic feet of Western Australian mahog-

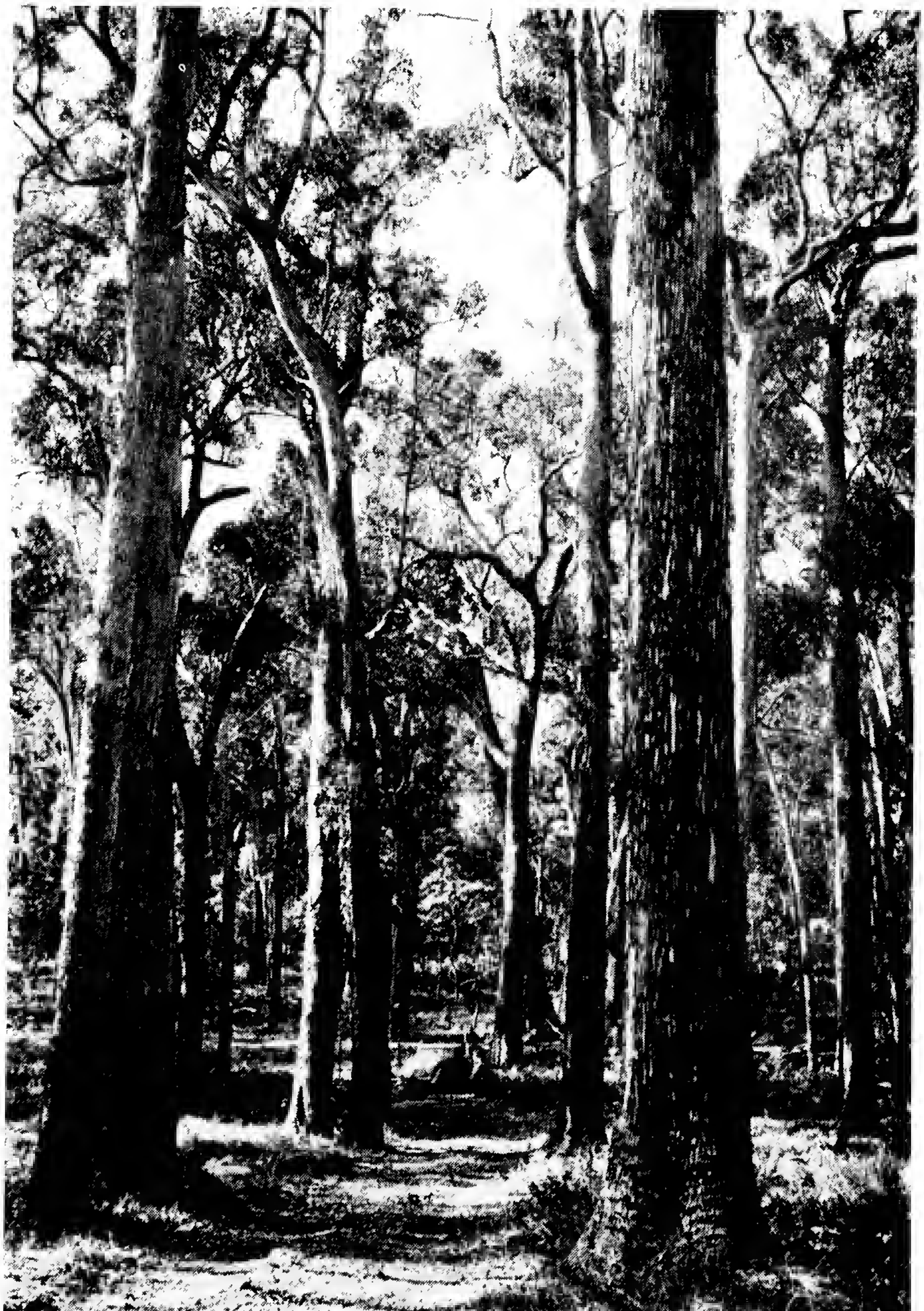

Figure 1.—Virgin jarrah forest.

any, as it was then called, for the naval dockyards in England. For the following ninety years exploitation of the jarrah forest continued unabated and uncontrolled.

Concentration of sawmilling operations during this early period was in the northern forest area, while the southern half of the forest region remained virtually untouched until after 1920.

In the period prior to 1920 nearly one million acres of the jarrah forest were cut over for the removal of 750 million cubic feet of logs, causing a reduction of almost 50% in the forest canopy.

While the operations of the sawmillers involved the removal of logs from the forest, the tops of the trees were left behind, and without organised control no action was taken to dispose of these piles of fuel, or to reduce the fire

hazard that had been created. In consequence, when a fire did occur in the area, it was of extreme severity—a far different proposition from the light fire of previous centuries.

Measurements have shown that only half to one third of the standing tree is used by the sawmiller and as 20-30 tons of log timber were removed per acre, an equivalent weight of debris was left behind on the forest floor. This must be compared with the average two-year old fuel bed of the virgin stand. Hatch (1955) has found that the fall of litter in an average virgin jarrah stand is about one ton per acre per annum, with an accumulation of 2 tons in 3 years, allowing for normal decomposition over that period (Fig. 2). The addition of some 20-30 tons by the felling operation, even though some of this would have been heavy branch wood, was a highly significant factor in the burning regime of the forest. This mass of fuel, even if burnt in the summer following the milling operation, would have produced a fire of extreme severity, but where tops were felled in a recently burnt area they may have survived unburnt for two or three years, by which time the debris would have had time to dry and the resulting fire would have been even more damaging to the remaining trees and to any young growth which may have resulted from the felling operation.

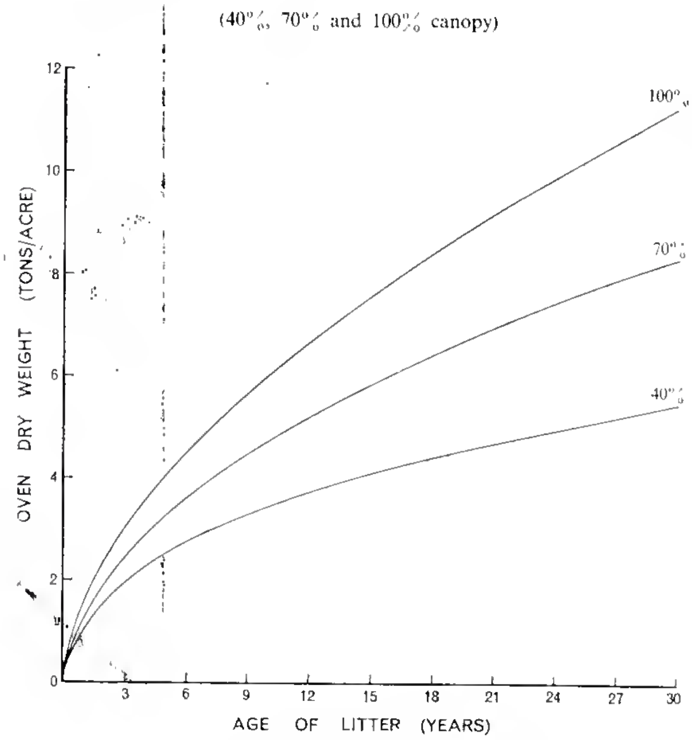

Figure 2.—Litter accumulation in the jarrah forest.

The holocaust arising from fires, under these conditions, caused complete defoliation and great damage to those trees remaining on the area (Fig.3): damage which permitted the ready ingress of insect borers and rot fungi. Although the unexploited virgin forest still remained an area regularly burnt and with a 0-4 year old fuel bed, the area of virgin forest immediately adjacent to the severe fire area also sustained serious damage—particularly in the crowns. As sawmilling operations became more extensive, severe fires became more frequent and more widely scattered throughout the forest area. At the same time, fires associated with clearing for agricultural purposes in the forest region were becoming more prevalent and an increasing source of forest fires.

In the early days of colonisation little notice was taken of these fires because they were small in relation to the forest area; however, as utilisation and clearing gradually increased in tempo fires increased in number, size and severity. Under the repeated onslaught of this type of fire the forest suffered heavily.

Gradually the public conscience awoke and there were periodic outcries for conservation and protection of this forest heritage. The first ordinance relating to the control of fire was passed in 1847 and the first Bush Fires Act in 1885. They did little more than define a prohibited burning period and, as they were not policed, had little effect on the problem.

Forest conservation and protection were virtually non-existent until the passing of the Forests Act in 1918, and even after this date it was some years before the new department was able to recruit sufficient staff to make much impression on the task before them.

Forest management and protection

Faced with the scarred and blackened boles of the cut-over areas and the grossly malformed stems of the young second growth trees, together with the mass of scrub and weed trees on the one million acres of cut-over forests, the newly appointed foresters found themselves with staggering problems in both fire protection and silviculture.

Fierce fires were the rule where sawmills were operating and serious damage had been inflicted, also, on parts of the remaining virgin stand.

Even in the southern forest region some fire trouble was being experienced, mainly from cattle drovers passing through the forest to the grazing country along the southern coast—and from clearing fires in settlement areas.

The problem was tackled from three angles:—

1. The continued protection of the virgin forest.
2. The reduction of debris following current felling operations—which were extending at the rate of 50,000 acres per annum.
3. The rehabilitation and protection of the backlog of 1,000,000 acres of forest cut over during the previous century and grossly damaged and degraded by periodic severe fires.

The protection of the virgin stand was relatively simple and was maintained by regular broadcast controlled burning in the cooler months of spring and autumn.

The mass of debris resulting from current felling operations had been, over the history of timber utilisation, the main cause of the disastrous fires in the forest area and the removal of this mass of fuel at the first suitable opportunity seemed to be the answer. The whole sawmilling operation was slowly brought under management as the following regime was introduced. Felling operations for each sawmilling permit were confined to an annual cutting coupe. This coupe was burnt through in advance of the felling operation and the trees marked for removal by the forester thus fell on a clean floor. The felled tops were lopped flat and any debris around the butts of standing trees was cleared away for a distance of 3 feet. The tops were then burnt in the following spring or autumn with minimum damage to the remaining stand. The area was thus rendered safe from fire for several years, and was included in the area receiving complete protection.

Figure 3.—Severely fire-damaged forest.

The backlog of older cut-over areas presented a more difficult problem and a compartment system of protection was devised where 500 acres of cut-over forest was given a suitable regeneration treatment involving the cutting down of the malformed regrowth at ground level, with a view to inducing a coppice crop from which future final crop stems could be selected. Understorey weed trees were felled and useless members of the original stand disposed of by ringbarking. This ringbarking, however, added considerably to the fire danger and difficulty of fire suppression and was abandoned after a few years.

Compartments were surrounded by a fireline about 2 feet 6 inches wide formed by a heavy scraper dragged by a horse. This fireline, or scraper track, defined the treated compartment on one side and a firebreak five chains wide on the other. These firebreaks were to be burnt every three years and the compartments protected from fire until the young growth had reached a height which would allow a light controlled fire to run through the area without causing crown damage.

Work in this direction proceeded steadily, centred on the forest settlements which were slowly being established throughout the forest area. Early operations were concentrated in the northern forest and moved slowly south as staff and money became available. For all operations access roads had to be developed, and in this reasonably undulating country were achieved at low cost. There are now 17,000 miles of forest roads of various standards throughout the south-west.

Detection of uncontrolled fires was necessary so that action could be taken for their suppression before they could menace protected forest and private property in and near the forest. A system of lookout towers situated on strategic high points throughout the forest area was planned for the location of fires by cross-bearings. The first was erected on Mount Gunjin in the Mundaring district in 1919 and the whole forest area is now adequately covered by 38 towers.

Suitable communication from lookout tower to forest headquarters and to the field firefighting gangs was essentiail. Initially, communication was by heliograph but this quickly gave way to an efficient earth return telephone system which eventually extended for 1,700 miles. Radio communication was attempted from Collie tower as early as 1928 but it was not until surplus equipment became available after World War II that radio came into general use to supplement the telephone. These high frequency sets had some disadvantages which unfortunately included poor reception during the worst fire weather conditions, but the system has been greatly improved by the recent substitution of V.H.F. units, of which 177 are now in operation.

Fire weather

The summer of 1933 was extremely hot and dry, with the worst heatwave on record in the month of February. Fires raged throughout the whole forest area, leaving a trail of damage in their wake. This prompted foresters to think more closely of the relationship between fires and weather, and in 1934 a fire weather research station was established at Dwellingup with the object of:—

1. finding some simple measure of fire danger at any time, and
2. exploring the possibility of forecasting fire weather.

Following the work of Gisborne (1928) and Stickel (1931) and after a study of the possibility of using individual or groups of weather elements. The fuel available varied from leaves to heavy branchwood and a further problem involved the selection of specimens of suitable size and shape which would give a reasonable representation of the moisture content of the faster burning debris. Jarrah leaf litter and various species and shapes of wood were tested and it was found that the most responsive and convenient unit was a half-inch diameter cylinder of locally grown *Pinus radiata.* For ease of measurements and calculation of moisture content a group of three cylinders with an initial over-dry weight of 50 grams was eventually used as a standard (Wallace 1936). A remarkable correlation was immediately apparent between the minimum daily moisture content and the average maximum hazard obtained from the personal estimates of field officers.

The term "fire hazard" was adopted for the burning conditions defined and the moisture content of the half-inch pine cylinder accepted in 1935 as a satisfactory measure of this factor. A graphical representation of moisture content and fire hazard was prepared for general use and standard ratings introduced (Low, Moderate, Average, High, Severe and Dangerous).

At this time a further problem arose in that there appeared to be a small but significant loss in oven-dry weight of the pine cylinders throughout the summer, with the result that apparent fire hazards read from the graph towards the end of the summer were too high. This was overcome by lowering the line monthly throughout the season and the use of new cylinders each year (Fig. 4).

No improved method of measuring current fire hazard has yet been found in this State and wood cylinder moisture content is still used as a basis for fire weather forecasting.

Forecasting fire weather posed a bigger problem than the measurement of current danger, and involved basic meteorological principles and the latest information available in the form of synoptic charts and upper air analysis. Reasonable progress was made in these early years and the effect of weather elements on the variation of fuel moisture content carefully analysed, but it was perhaps the regularity of the weather cycle over the southwest of this State that enabled an acceptable degree of accuracy in single observer forecasting to be achieved.

Fire weather forecasting was commenced at Dwellingup in 1936 and forecasts disseminated through the national broadcasting station. Two

years later, this service was passed over to the Commonwealth Meteorological Bureau who have issued forecasts of fire hazard on every summer day since that time.

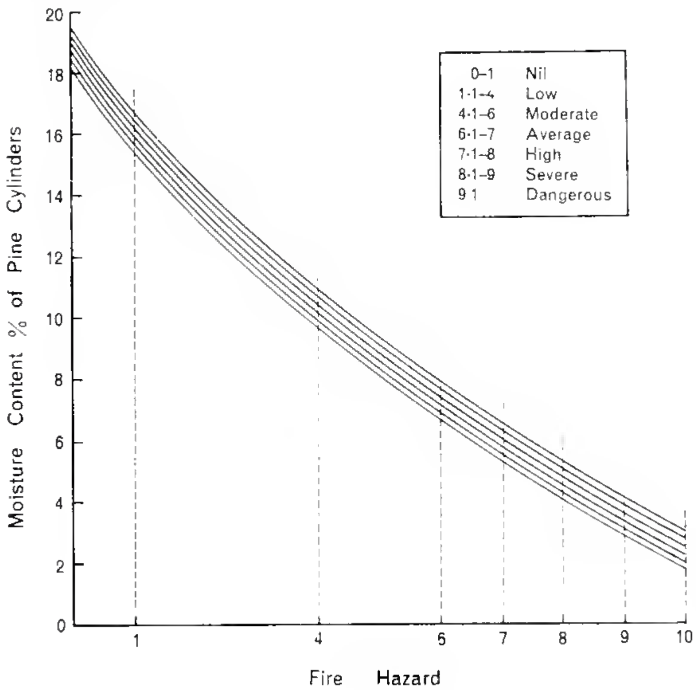

Figure 4.—Fire hazard in the jarrah forest.

Fire weather forecasts are composed of an estimate of the maximum fire hazard for the following day with details of wind force and direction, maximum temperature, relative humidity and other general weather information. With close co-operation between the State and Commonwealth authorities, a high degree of accuracy has been maintained over the past twenty-five years.

Summer weather over the forest area is governed by a series of high pressure systems which provide mild, dry conditions interspersed with periods of hot weather and high fire danger produced by a southern dip or trough from a tropical low pressure system usually centred off the north-west coast. Heat waves and maximum hazard occur when there is a southerly movement of the low pressure centre causing a stationary trough off the west coast. The relative instability of the air mass has an important bearing on the spread of a fire and its ability to throw spot fires ahead, and on the difficulty of suppression.

An analysis of the meteorological conditions relating to uncontrolled fires in Australia dating from 1914 was published by the Bureau of Meteorology (Foley 1947) and contains useful sketch maps of the weather situations for a number of major outbreaks in Western Australia.

Fire causes

O'Donnell (1945) has tabulated fire causes for the decade prior to 1943 and figures for the following 20 years are given in Figure 5. In general, they show that the forest region is the subject of over 300 fires each year and that there has been only a minor reduction in number over the period. Some major causes of fires have become less important over the years. Mill locomotives, once the main source of forest fires, have been reduced as a result of the steady replacement of steam by motor transport and the marked drop in fires from State railway locomotives in recent years has been influenced by the use of oil in place of coal. Fires from bush workers are less due to the introduction of power saws and reduction in number of fallers. Stockmen moving their stock through the forest areas, particularly in the south, and once the bane of the foresters' existence in that area, are no longer a source of trouble.

The most significant increases are in fires caused by lightning and by the Forests Department's controlled burning operations. The former, it is felt, is not due to any change in weather conditions but to improved and extended fire detection methods; previously a number of these fires were just not recorded while some were listed in other categories.

The number of fires escaping from departmental operations is directly related to the considerable increase in the area being burnt under the policy of extensive prescribed burning. It must be pointed out, however, that practically all of these fires occur in the cooler parts of the summer and that their area is small and little damage results.

Escapes from private property fires still present the main single cause of danger to the forest. These fires occur when the burning season opens in March and, burning in the driest part of the summer, are often of considerable size when they enter the forest. Second only to the fires in mill tops for the period prior to 1920, they have proved the most serious menace to the forest over the past 45 years.

Fire protection in the jarrah forest

In general, fire control organisation was aimed at:—

1. forward planning for controlled burning on a 3-year cycle;
2. early detection of wildfires;
3. rapid transport to the fire, and
4. speed in bringing the fire under control.

The main source of the initial devastating fires of the previous century was eliminated by the introduction of the top disposal operation. The total number of fires occurring was drastically reduced in the first decade of control but thereafter remained fairly constant in spite of continued attention to fire causes. Controlled burning of firebreaks and virgin forest areas appeared satisfactory and the backlog of cut-over country was gradually being brought under management. Methods had improved and the introduction of the knapsack spray as a major hand tool supported by the fire rake paved the way for organised firefighting units who received intensive training. More general use of motor vehicles after 1935 provided means of transporting gangs quickly to the site of a fire. Field fire gangs of 5-6 men were supplied with 3-ton trucks carrying a 200-gallon tank with low-down pump, knapsacks, rakes, axes, saws, portable telephone, first aid kit and iron rations. Tele-

FIRE CAUSES

(In 5-year Periods)

1944/45–1963/64 inclusive

	44/45–48/49		49/50–53/54		54/55–58/59		59/60–63/64		1944/1964 inc.	
	Total	Av.	Total	Av.	Total	Av.	Total	Av.	Total	Av.
Escape P/P. C.B.	293	58·6	472	94·4	446	89·2	320	64·0	1,531	76·5
Mill Locomotives	292	58·4	201	40·2	210	42·0	67	13·4	770	38·5
Escape F.D. C/B	113	22·6	115	23·0	188	37·6	226	45·2	642	32·1
W.A.G.R. Locomotives	278	55·6	88	17·6	162	32·4	44	8·8	572	28·6
Travellers	152	30·4	103	20·6	121	24·2	150	30·0	526	26·3
Deliberately Lit	45	9·0	197	39·4	87	17·4	114	22·8	443	22·1
Hunters and Fishers	123	24·6	102	20·4	102	20·4	84	16·8	411	20·5
Lightning	15	3·0	68	13·6	84	16·8	175	35·0	342	17·1
Children	38	7·6	36	7·2	87	17·4	104	20·8	265	13·2
Bush Workers	76	15·2	80	16·0	49	9·8	46	9·2	251	12·5
Mill Surrounds	33	6·6	40	8·0	61	12·2	43	8·6	177	8·8
Other Government Departments	30	6·0	38	7·6	60	12·0	33	6·6	161	8·0
Householders	34	6·8	38	7·6	49	9·8	38	7·6	159	7·9
Stockmen and Leaseholders	83	16·6	11	2·2	13	2·6	....	....	107	5·3
Tractors	2	0·4	9	1·8	12	2·5	31	6·2	54	2·7
Mine Surrounds	15	3·0	5	1·0	10	2·0	12	2·4	42	2·1
Firewood Cutters	23	4·6	9	1·8	8	1·6	2	0·4	42	2·1
Navvies	18	3·6	11	2·2	5	1·0	2	0·4	36	1·8
Gas Producers	13	2·6	....	....	....	....	....	....	13	0·6
Escape Prev. Fires	....	....	3	0·6	9	1·8	....	....	12	0·6
Motor Vehicles	...	....	....	....	5	1·0	....	....	5	0·2
Power Mains	....	....	....	....	1	0·2	3	0·6	4	0·2
Unknown	100	20·0	97	19·4	135	27·0	128	25·6	460	23·0
Totals	1,776	....	1,723	....	1,904	....	1,622	....	7,025	....

Figure 5.—Causes and distribution of fires.

phone contact was maintained with forest headquarters or the nearest lookout tower and the fire gang coulld be despatched to any outbreak without loss of time. Gangs were trained to a high peak of efficiency; morale was high and it seemed as though the fire problem was well under control. Newly cut-over areas of 50,000 acres were being coped with and an average of a further 50,000 acres of the backlog brought under protection each year.

In 1945, however, O'Donnell, the forest fire control officer pointed out that, during the previous three years controlled burning operations had lagged seriously and that the planned programme had not been maintained. He considered that this was to some extent due to lack of manpower during the war but also emphasised that the hazards of firebreak burning had increased considerably as areas protected from fire had, over the years, accumulated masses of debris in the form of leaf litter, branchwood and dead shrubs and, also, that the unburnt bark of the trees had reached a highly inflammable condition. Burning of firebreaks around these protected areas was becoming increasingly difficult; sparks caused fires in the adjoining protected country which were difficult to suppress, and time lost in suppressing these hop-over fires was time lost in controlled burning. Furthermore, as debris in the protected areas increased and the danger in burning protective firebreaks increased in the same order, cooler weather had to be selected for controlled burning activities and this in turn reduced the number of days on which the burning could be attempted and the total amount of burning which could be completed. Factors generally adverse to successful fire protection were snowballing.

Operations were streamlined by increasing the size of compartments to 1,500 acres and reducing the mileage of firebreaks involved; firelines were straightened, widened and improved to carry motor transport; heavy duty fire equipment in the form of 5-ton trucks loaded with 600 gallon tank and power pumpers was introduced. This improved the situation for a period but fires in long-protected areas were still causing grave concern. Breakaways from controlled burning were common and, even though these occurred in the milder spring weather, were still serious. Where uncontrolled fires started in mid-summer in these long-protected compartments the resulting fires could be contained only after the loss of large areas, at considerable expense, and with the assistance of firefighting forces from outside the home district.

Following extensive fires in forest east of the Albany Road in 1949, and the Plavins fire of some 30,000 acres in 1950, it was becoming apparent that the ability of the firefighting forces to control fires within the limits of forest economy, in the 2,000,000 acres then receiving protection was in doubt. Further trouble and declining morale of the firefighters forced a serious reconsideration of policy. In 1954 the momentous decision was made to replace the complete protection policy of the past 30 years with one of prescribed, broadcast burning in an attempt to reduce the damage from wildfires in previously protected forest.

This change in policy produced its own complex of problems, not the least of which was to break down the hazard built up in the protected areas over a long period of years. It was impossible to burn this heavy accumulation of fuel, even in spring, without serious damage to the growing stock. The only answer was to reduce the debris by periodic fires, the first of which would need to be in the winter months when, unfortunately, the days on which burning could be undertaken were limited. Rather than concentrate on completely reducing the litter on a small area, it was decided to burn the top litter over the greatest possible area but there was little doubt that 10-15 years would be needed for the complete reduction of the accumulation of the previous 25 years if serious damage to the forest regrowth was to be avoided. There was a further complication because, while the flash fuels were being removed over a wide area, the sections burnt first were themselves again increasing their fuel from the annual leaf fall. Progress was slow and some serious breakaway fires still occurred, but the position was improving gradually as the tempo of controlled burning increased.

The forest area at Dwellingup was typical of the results of a tight protection policy. In an area of some 450,000 acres, 90% was under full protection by 1954. There had been an all-out effort to reduce leaf litter accumulations of up to 25 years over the seven years to 1961 but success had been only partial for, while the top litter had been removed over a large part of this area, critical amounts of fuel remained over wide areas, broken only by occasional recently burnt firebreaks and some more extensive areas of broadcast burn. The position was serious then in January 1961, when a widespread conflagration was started by 22 lightning fires in 24 hours. This wildfire ultimately developed into the most extensive fire in the jarrah forest in the 40 years of fire protection. It covered 350,000 acres of forest, and air-photos and subsequent field checks revealed that there had been 65,000 acres completely defoliated, 120,000 acres where the majority of the crowns were browned (that is, the leaves killed but not burnt off), and the remaining 165,000 acres relatively undamaged. If medical terms could be used these fires could be referred to as third degree, second degree, and first degree burns respectively.

Practically the whole area of this fire was in country cut-over variously between 5 to 60 years and carrying young jarrah pole growth of a similar age range together with the remainder of the old forest trees not removed in the original or subsequent milling operations. Debris on the forest floor varied with age since the last cutting and the protective treatment over the previous 25 years.

The damage sustained in the third degree burn included the death of a proportion of the old veterans, "crown kill' in others, with epicormic response in the boles and, in the more vigorous trees, defoliation with crown recovery. Serious damage to the younger members of the stand occurred and many of the suppressed trees were killed. The dominants of the regrowth stand, however, survived reasonably well but were the subject of bole damage in the form of butt scars and dead patches along the length of the trunk. This is particularly serious in trees halfway to maturity as this bole damage will later cause serious defects in the middle wood of the mature log—the region where the best timber in size and soundness may normally be expected. The outstanding power of recovery of jarrah has already been referred to and the difference in appearance of these heavily burned stands after a period of 3 or 4 years is remarkable.

The area of second degree burn suffered somewhat similar damage to the above, but of a lesser order. Complete crown defoliation was rare but although some old trees were killed bole damage was less and recovery of the dominants produced less bole epicormics. In both areas dense fireweeds, particularly *Acacia pulchella*, thrived and these will be a serious handicap to forest operations and controlled burning during the current decade.

The first degree burn occurred over those areas which had been the subject of satisfactory controlled burning in the previous two years. The results were similar to those expected with controlled burning on a hot day and caused only the minimum of damage. It did, however, show very clearly the value of prescribed protective burning in reducing damage from wildfires even under the worst possible weather conditions.

Prescribed broadcast burning

In recent years considerable research has been undertaken into the factors governing periodic controlled burning and its practical application to the protection problem.

It must be emphasised that controlled (or prescribed) burning is aimed at the reduction of fuel over a wide area within the boundaries specified and within the scorch heights acceptable. It does not seek primarily to remove all litter from the forest floor at any time, but is concerned with maintaining the forest in a condition where wildfire may be readily contained and damage kept to a minimum. In view of the great area involved the operation is extensive rather than intensive, and in the jarrah forest is directed towards a complete cover of the forest area every five years. This means the prescribed burning of more than 800,000 acres per year and cannot be achieved without the maximum effort and efficiency of all fire protection personnel.

McArthur (1962) working in both jarrah and Eastern States eucalypts has produced data of considerable value and has devised a series of graphs from which rate of spread, flame height and scorch height may be determined for varying conditions of weather, fuel quantity and fuel moisture content. Peet (1962-65) working from the Fire Research Station, Dwellingup, has modified McArthur's findings to deal specifically with jarrah and the practical problems associated with controlled burning in this forest.

A number of interesting criteria have been produced by these workers who suggest that the critical scorch height which should not be exceeded is 20 feet and that the relationship of scorch height to flame height in the jarrah forest is of the order of 7:1 in summer, and 14:1 in autumn. This limits the flame height to 3 and 1½ feet respectively. While this constitutes the maximum acceptable it borders on the risky and the greater part of the area to be burned should be covered by a less intense fire. McArthur's suggestion that it should be possible to step over the flame in a controlled burn is a fair guide to acceptable fire intensity.

The practical application of precise criteria for burning is most important from the angle of total area to be burnt. The prescribed burning of 800,000 acres per year with a total force of about 300 men means that each individual must burn over 2700 acres per season. On an average, a total of only 45 days of suitable controlled burning occur during the spring and autumn months. Forty acres per manhour, using fusee matches, has been suggested as a desirable norm for controlled burning but it seems doubtful whether this can be maintained over a whole season and a figure of 20 acres would seem more conservative for the whole forest range. This would require full use of every available burning day outside the summer months. If 20 acres per hour can be maintained the prime cost of the operation would be 5 cents per acre, or about one cent per acre per annum on a five year burning rotation. This is an extremely low fire insurance on a valuable crop of standing timber. Much higher insurance values could be accepted but the critical factors are availability of manpower and money and the huge area which must be burnt annually if prescribed burning policy is to be effective.

The designed method of burning on an area basis is by a grid system of spot fires, each small fire being left to burn out to meet its neighbors. It is obvious that the wider the spacing between the spots the greater the area burnt over by the gang in one day. The widest spacing is desired for another season—the junction zone between any two fires is an area of more intense fire, flame height and scorch height. Where spots are 1 chain apart 50% of the area may be subjected to the higher intensity fire; with 10 chain spots the figure is reduced to 10%.

A series of tables has been evolved to assist in the technique of controlled burning within the limits of a satisfactory reduction of the forest fuel and an acceptable scorch height for the section of forest concerned. The method is based on the forecast maximum hazard for the day, corrected for amount and period since last rain. To this adjusted fire hazard is applied the wind force, in miles per hour, (taken from the nearest lookout tower) to assess the forward rate of fire spread in a 5-year old leaf litter which is taken as the standard. The rate of spread in 5-year old litter is then corrected for the actual age of litter in the area to be burnt, and this same table gives the scorch height for the conditions prevailing. If the scorch height is acceptable then the next table, taking into account the number of hours available for the operation, indicates the distance between the lines of spots. For safety reasons the lines are run at right angles to the wind direction and the spots along the lines are half the distance between the lines.

In a search for more rapid and effective methods of controlled burning over extensive areas in a short period field trials have been undertaken recently using an airborne incendiary as the lighting agent.

A light push-pull twin-engined aircraft was used in this project, flying along previously defined parallel lines and dropping small incendiaries from a height of 300 feet above treetop level. Radio contact was maintained with a ground control and check markers (hydrogen-filled meteorological balloons) were established at strategic intervals.

Effective lighting was carried out over 52,000 acres at the rate of 3000 acres per hour of incendiary dropping time, at a cost only slightly higher than the normal ground operation.

This form of lighting has distinct advantages over the normal methods. The whole operation is speeded up and large areas may be stripped when only limited periods of suitable weather are available. Periodic shortages of manpower could become less important and forests with limited reading would be more readily protected. There is little doubt that with improved techniques aerial lighting heralds a major advance in the controlled burning programme.

Growth rates following fire

An interesting sidelight on severe fires leading to defoliation or browning of the jarrah pole crowns was revealed after the Plavins fire in

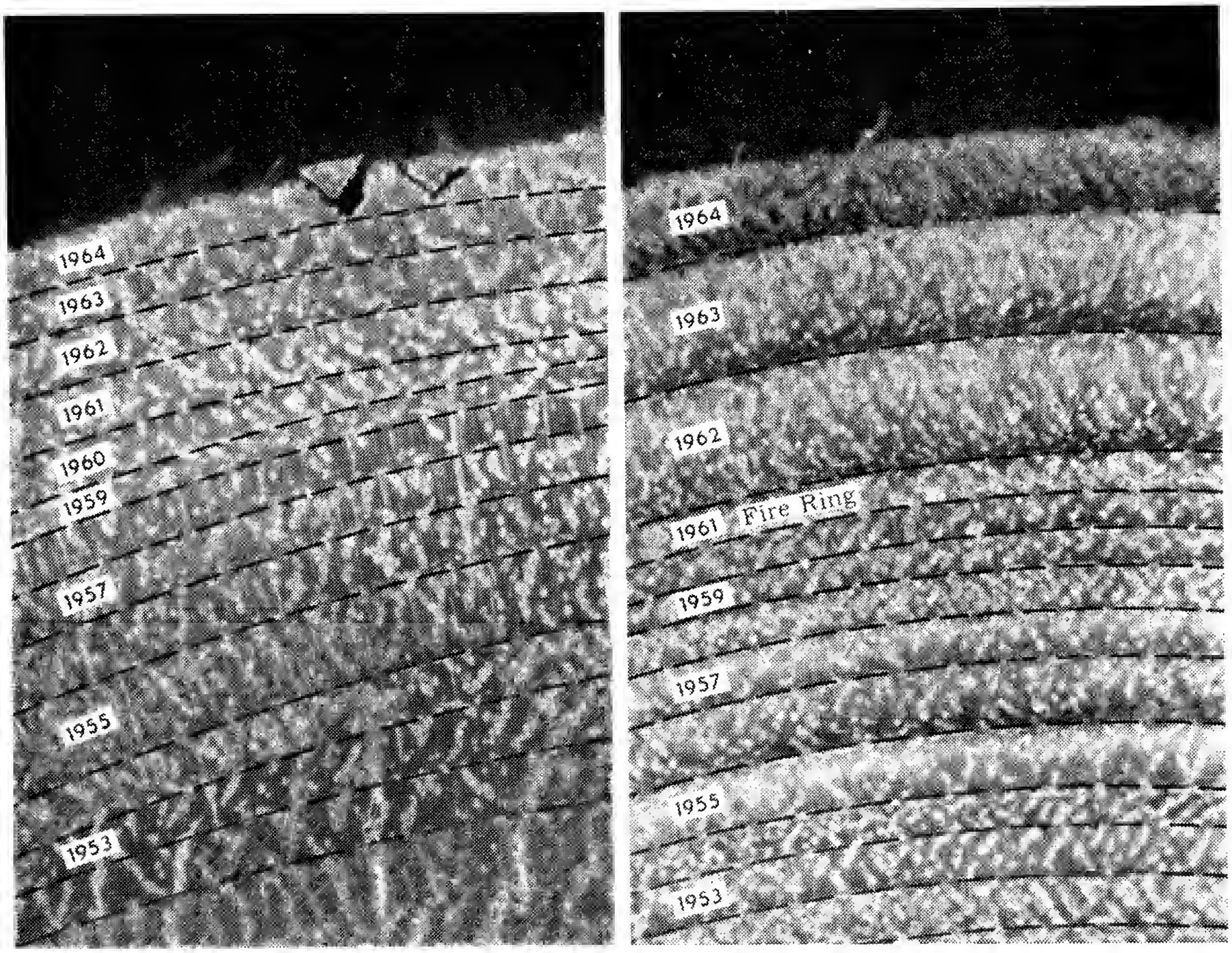

Figure 6.—Increased growth rate following 1961 fire (right) compared with unburnt control (left).

1950, when it was found that there was a virtual cessation of growth immediately after the fire but a surge of growth for the following four or five years. Further work on this phenomenon has been carried out since the Dwellingup fire in 1961 and annual basal area increments up to four times greater than the pre-fire figures have been measured (Fig. 6). It is thought that this is due to the sudden availability of ash nutrients following the fire, to the temporary removal of scrub and weed-tree competition, the reduction of numbers in the major stand through death of some members and the flush of vigorously synthesising young growth in the new epicormic crown. While this increased growth rate is something on the credit side of a severe fire, it certainly does not offset gross mechanical damage to the growing stock and cannot be used as an argument in favour of massive fires at infrequent intervals.

Summary

Uncontrolled fires of the first century after the colonisation of Western Australia left a legacy of devastation to the forest service established after 1918. One million acres of the forest area had been cut over and seriously damaged by uncontrolled fires, sawmilling was proceeding at a high level and newly cut areas were increasing at the rate of 50,000 acres a year. As forest centres became established silvicultural operations to replace the fire-damaged forests were instituted and went hand in hand with protection of these areas. Disposal, by controlled burning, of tops left by current milling operations was undertaken annually as soon as weather conditions were suitable, and the major source of fuel which had caused the severe fires of the past was eliminated.

Complete protection of compartments by a fire-break system while the new growth became established and attained a height growth above the scorch height of a controlled fire was maintained and extended to cover past cut-over areas. This form of protection, combined with immediate and vigorous suppression of wildfires, was successful for a period of 25 years in reducing the severity of uncontrolled fires and protecting substantial areas of forest during the regrowth period. While this was reasonably satisfactory over 2 million acres, it could not be applied over the total forest area for economic reasons.

The policy of complete protection, however, gradually built up its own problems by the accumulation of debris in the protected areas. This eventually reach the stage where the rate of

protective burning was slowed down to a dangerously low level and the number of damaging fires was increasing in the long-protected areas. In spite of increased expenditure and the provision of more and heavier equipment, it became necessary to abandon the protection policy and institute one of broadcast controlled burning. This was no immediate solution to the problem as the fuel accumulated over 2,000,000 acres would take 10-15 years to reduce to safe proportions. The unfortunate and disastrous fires at Dwellingup in 1961 did little to help the position except that it did increase the emphasis on research into prescribed burning and, although this work must continue, some of the results are already being put into practical use, leading to a marked improvement in the efficiency of controlled burning techniques.

Now that most of the heavy fuel accumulations have been eliminated the present policy should provide more satisfactory protection to the whole of the 4 million acres of jarrah forest area, at the same time providing a reasonable balance between the silvicultural requirements of the stand and the need for protection from serious fires. Wildfires will continue while the causes remain, but these fires will be more difficult to start and more readily controlled where the maximum accumulation of litter over the greater part of the forest will be no more than five years of age.

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6.—The Frenchman Bay meteorite

by G. J. H. McCall*

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Abstract

An "iron-shale" encrusted boulder recovered from barren country south of Jurien Bay township, Western Australia, has been recognised as a stony meteorite, deeply weathered. It is a chondrite of spherical type, containing a substantial amount of glass in the chondrules and interstitial to them. X-ray diffraction determination of the olivine shows it to be Fa_{19}, indicating that this is an olivine-bronzite chondrite of Prior's class 2. Details of the chondritic structure are given and an unusual fusion crust pattern is described. There is little or no evidence of recrystallisation.

Details of the find

On 28 September 1964 Mr. R. L. Devitt and Mr. J. H. Turner, both of Perth, noticed a boulder amid limestone outcrops and sand dunes south of Frenchman Bay, some miles from Jurien Bay township, on the west coast of Western Australia. The exact location of the find is shown in Figure 1. It was made at a point 8 miles south-southeast of Wealacutta Pool, Frenchman Bay, and 3 to 4 miles inland from the sea, in an area marked by a small watercourse, the Nambung River, which hereabouts becomes lost amid sand dunes at its seaward termination. The co-ordinates have been estimated as 30° 36′ 30″ South, 115° 10′ East. The terrain is barren and inhospitable, being characterised by numerous limestone pinnacles, arranged like tank traps and rising from bare sand (Figure 2).

Traces of aboriginal habitation were noted by the finders near the site of the find, and, since aboriginals are known to cherish meteorites (especially australites) as "magic stones", human transport from a site of fall elsewhere cannot be entirely discounted (cf. the numerous meteorite recoveries in American Indian country where the same sort of doubt exists; Nininger 1952 p.7-8). Because of the size of this meteorite, however, such a happening seems unlikely and we may safely assume that this was the actual site of the fall.

Figure 2.—View of the site of the find, looking seawards.

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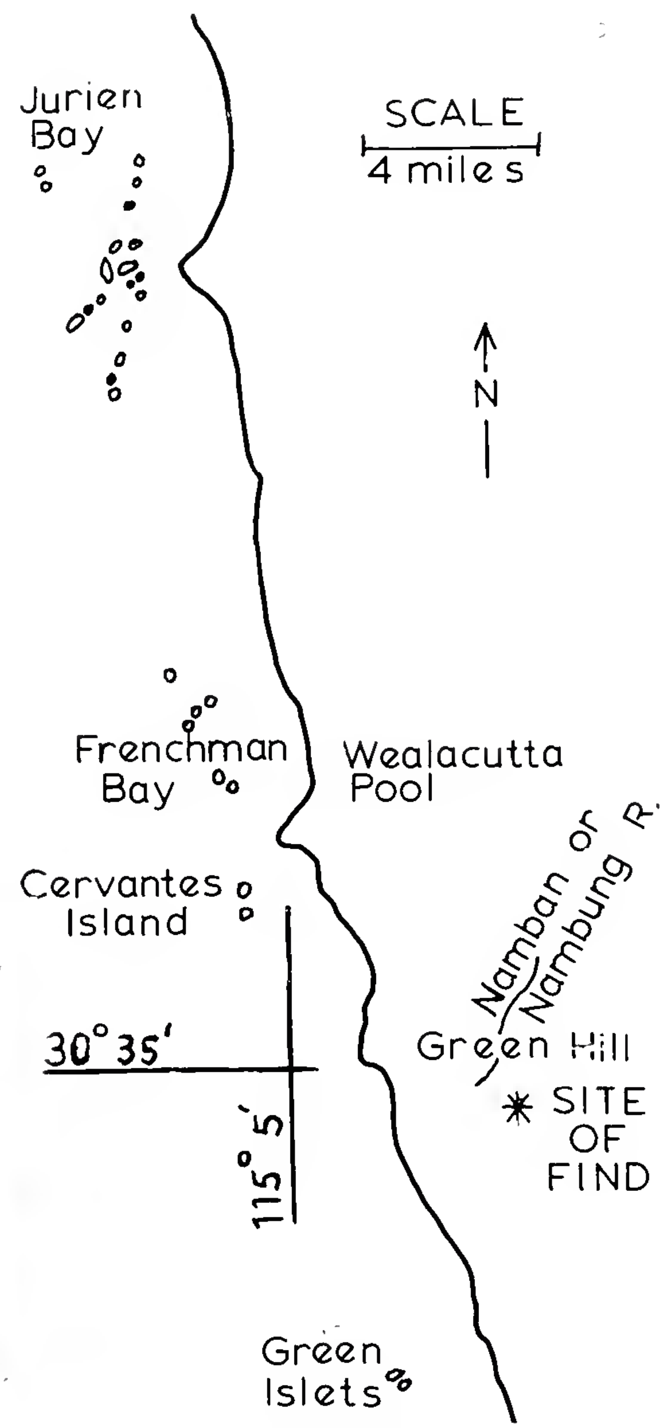

Figure 1.—Sketch map showing the location of the find.

The finders transported the boulder to Perth, where the writer was asked to examine it. Unpromising as it appeared at first sight with its flaky coating of "iron-shale", its high density, the semblance of a facetted surface, and a patch of fusion crust at the narrow termination, combined with Mr. Devitt's assertion that it was exotic—"a foreigner"—led to a suspicion that it might be a highly weathered meteoritic stone. This suspicion became a certainty with the first cut of the diamond saw, for a greenish-grey core punctuated by spherical chondrules appeared. Microscopic examination confirmed this and also the tentative identification of a black patch on the narrow termination as fusion crust.

Physical properties and external features

The mass is a single, flattened, crudely pear-shaped body, possessed of one broad, blunt termination, and one narrower, rounded termination (Figures 3 and 4). The total weight before cutting was 19.4 lbs (8.8 kg) and the maximum dimensions were 10 x $7\frac{3}{4}$ x $4\frac{1}{4}$ inches. Up to $\frac{3}{4}$-inch of oxidised, scaly crust, an "iron-shale" composed largely of limonite, was revealed on sectioning the mass (Figures 3 and 4). The transition to comparatively fresh core material is somewhat abrupt. The limonitic crust is cracked and flakes off readily, but the core material is compact and cohesive.

The specific gravity of core material, measured using carbon tetrachloride, was found to be 3.20, considerably lower than the average for the common types of chondrites (3.51 for olivine-hypersthene chondrites and 3.6-3.8 for unweathered olivine-bronzite chondrites; Mason 1962), but this anomaly is not significant in view of the decomposed state of the nickel-iron/troilite fraction.

Fusion crust is only preserved in an oval patch, measuring $2\frac{1}{2}$ x 2 inches diameter and situated in a hollow area at the narrow termination of the mass (Figures 3 and 5). It is dull, black and of variable thickness, locally exceeding 1 mm. The rough character and thickening suggests that it may well represent a posterior ablation surface in atmospheric flight, but there is no other indication of flight orientation (cf. McCall and Jeffery 1964 pp.36-38).

Figure 4.—Views of the single mass after cutting off the pointed termination with the diamond saw. The rough, cracked ferruginous crust is evident in all three photographs, and the first two show the facetted form of the mass. The lowest photograph shows the dark, fresh core, speckled with spherical chondrules, within this thick crust. The mass shown is 8 inches long, and the width of the cut face is 5 inches.

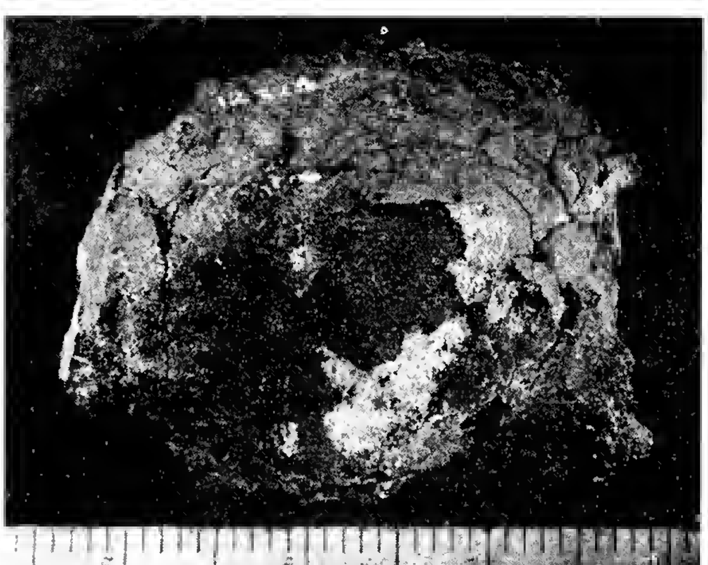

Figure 5.—The section cut off the narrow termination of the mass, showing caliche encrustation (white) and an oval patch of fusion crust (dark), on an otherwise monotonous "iron-shale" crust.

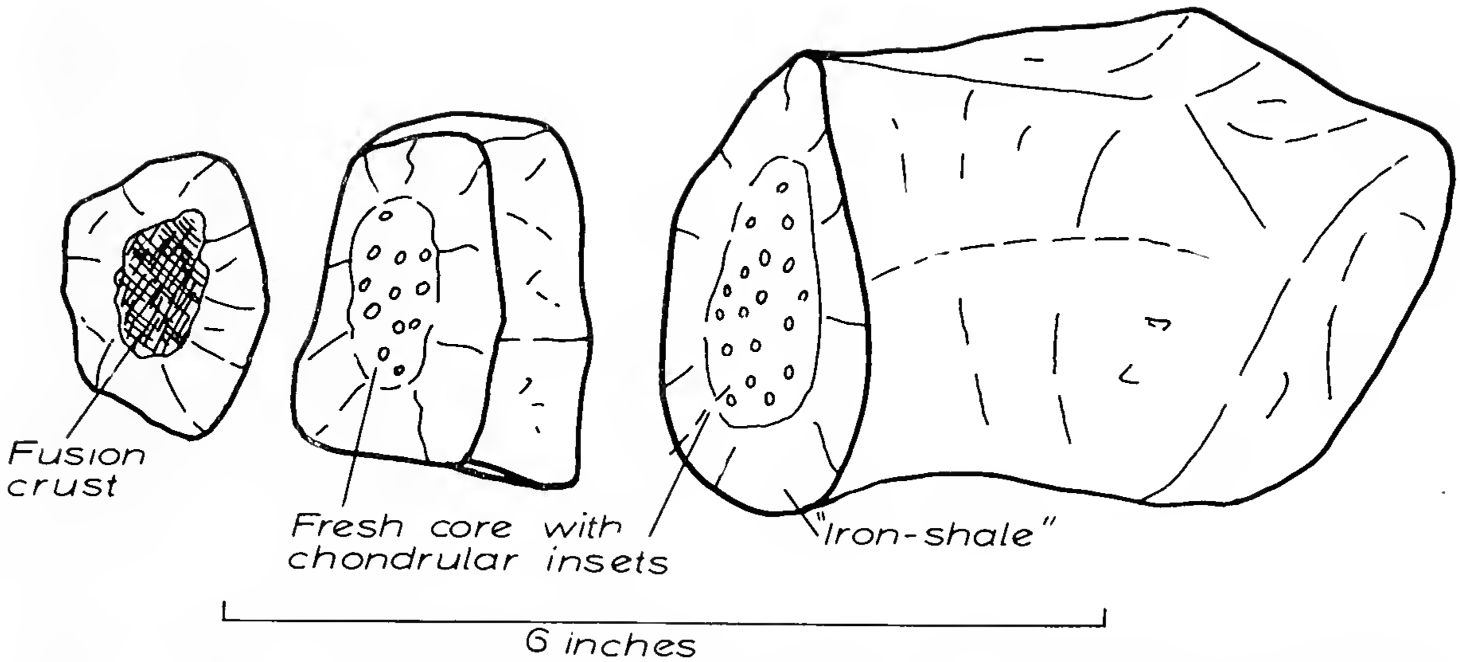

Figure 3.—Drawing of the entire single mass after cutting through the narrow terminatino with the diamond saw. Facetted form, terminal fusion crust coated area, and relation of fresh core materil to "iron shale" crust are shown.

Microscopic detail

Fusion crust

This is best seen under a binocular microscope using low magnification and oblique reflected light. The texture is mamillated in the manner of a blackberry fruit—it seems to be the type called "warty" by Krinov (1961 pp.270-272). The warty protuberances are clustered sporadically on a rough surfaced layer of compact, black glass about half a millimetre thick (Figure 6), and produce an irregular thickening of the crust. They are, perhaps, best described as mamillations. Also projecting from the compact crust, at all angles, are flat hexagonal plates up to 1 millimetre diameter. These show concentric lines on their side surfaces, parallel to the edge of the hexagon. They are well formed crystals of some mineral. There are two possobilities, nickel-iron (Krinov 1961 pp.273-4) or troilite. The former seems unlikely and it is more probable that these are troilite plates, recrystallised by the heat of ablation. The crystal form appears to be that of troilite. These hexagons are overlain by the mamillations, giving a shiny lustre instead of a dull grey surface, and it is certain that the mamillations were superimposed on the hexagons.

Comparison with the fusion crust of another chondrite (Woolgorong; McCall and Jeffery 1964) under a single field of view of the binocular microscope leaves no doubt that this is a relic of the fusion crust, not a secondarily derived goethite surface, due to terrestrial agencies. The crust was studied in crushed particle mounts under transmitted light and was found to include brown, isotropic glass containing minute vermiform inclusion, and also radial clusters of anisotropic fibres. The latter could also be recognised under oblique reflected light in a large, broken mamillation, and so cannot be dismissed as artifacts due to crushing. They show straight extinction and are interpreted as due to shock during atmospheric flight or on impact, and having originally been isotropic glass. Iridescence is locally evident on the mamillated surface and could also be due to shock.

Krinov (1961 p.270-272) explains warty protuberances on fusion crust as due to spattering: material ablated free from the tail end is supposed to catch up with the meteorite as it decelerates to the point at which all cosmic velocity is lost. The superimposition of the mamillations on the hexagon does suggest a late spattering effect, but it seems possible that a less

Figure 6.—Drawing of the fusion crust made under oblique reflected light with a binocular microscope. Microbotryoids are superimposed on hexagonal plates. The diameter is 2.5 mm.

complicated explanation could be found. No record of a fusion crust of this exact type could be found in the literature, though it is possible that such a texture has been described in some text not familiar to the writer.

Core material

The texture of the relatively fresh material of the core shows up well under the binocular microscope using oblique reflected light. The chondrules are seen to be predominantly spherical and the majority are complete, though there are some broken fragments indicating limited brecciation. Some complete chondrules appear distorted without actual fragmentation. Narrow cracks, many of them infilled with iron oxides, form a close network, some being micro-faults which displace oppsing halves of individual chondrules relative to one another. It seems likely that most of these cracks were initiated within the parent body before disruption, long before the meteorite came into contact with the Earth's atmosphere. The reason for believing this stems from the recognition of many troilite infilled cracks within fresher stony meteorites (McCall and Jeffery 1964 p.38-9; McCall 1966). From the amount of iron oxide in the cracks traversing this stone it is assumed that they have contained troilite. It does not seem likely that troilite could fuse, penetrate cracks through the meteorite and recrystallize again under the influence of ablation, but in view of the evidence of possibly recrystallization of troilite at the fusion crust surface this cannot be entirely discounted. Some cracks may be due to shock on impact and have suffered purely terrestrial infilling by ferruginous material. There is little trace of troilite now preserved, though traces of kamacite are still evident, and precise interpretation of the cracks is difficult. There is no trace of a directed texture, comprising troilite and nickel-iron flecks as in the Dalgety Downs meteorite (McCall 1966).

Thin section study under transmitted light also reveals the spherical texture of the chondrite (Figure 7 A and B). The chondrules are set in a sparse, opaque base which has probably been a ferruginous glass interspersed with kamacite and troilite grains. The chondrules themselves are largely iron-free, but some show dark, ferruginous haloes. The matrix contains fragments of the minerals present in the chondrules, probably material derived from disrupted chondrules and indicating that, in spite of the perfectly spherical form of most of the chondrules, the texture shows some reflection of penetrative brecciation at an early stage in the history of the meteorite, in addition to localised rupture by microfaulting, part or all of which may be late.

There is a wide variety of chondrule types. Monosomatic, barred olivine chondrules are evident, though scarce (Figue 9A). Polysomatic chondrules, including excentric fan (Figure 9A), finely grated and microporphyritic types (Figure 8) predominate: some of the latter show vitrophyric character, having an interstitial matrix of clear, clove-brown glass separating the olivine crystals, some of which show euhedral, gable-ended form (Figure 8A). Of particular interest

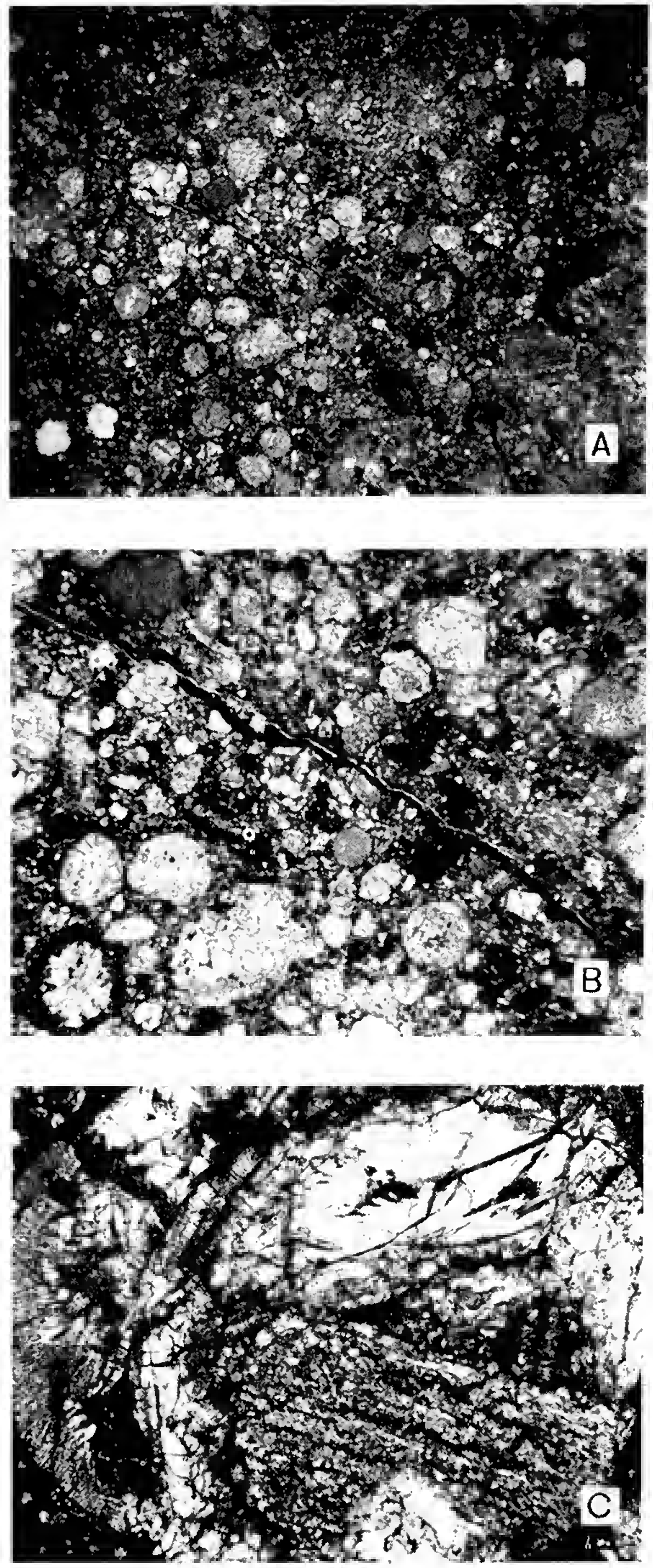

Figure 7. A.—"Spherical" chondritic structure (x6.5, plane polarised light). B.—Part of the same, enlarged to show the broken nature of some chrondrules, the dark ferruginous selvedge of others, and the fine, iron oxide filled fracture lines (x16, plane polarised light). C.—A large composite chrondrule, containing olivine in euhedral form (upper, right) and barred form (lower, right), orthopyroxene (extreme left) and glass (interstitial, dark). Barred, (lower right), microporphyritic (upper right) and excentric fan (extreme left) textures provide a textural inhomogeneity, in addition to the mineralogical inhomogeneity. (x40, plane polarised light).

are the composite chondrules: these have a two-fold composite character, being composed of more than one mineral and evincing more than one of the textural types of chondrules, first described by Tschermak (1885). The largest chondrule in the two thin sections prepared contains olivine, hypersthene and interstitial glass, and, in addition, three distinct textural types are seen in sectors which together comprise the chondrule—microporphyritic, barred, and fan textures (Figure 7C).

Mineralogy

Olivine occurs as euhedral crystals, subhedral grains and within grated and barred chondrules. Its moderate birefringence contrasts with the lower birefringence of the orthopyroxene. It has been determined by X-ray diffraction as $(Mg_{.81}\ Fe_{.19})_2\ SiO_4$.

Orthopyroxene is the only other silicate mineral identified, and is the most abundant. It is a non-pleochroic variety, and occurs mainly in fibrous aggregates, though there are also some broad, elongated crystals present. In some fan chondrules the fibres are so fine that the chondrules are cryptocrystalline (Figure 9A) but brush polarisation with straight extinction is apparent under high magnification, showing that crystalline material predominates, though glass may also be present. Physical separation of grains and more refined methods of study would be needed to determine both $MgSiO_3/FeSiO_3$ ratio and alumina content with a high degree of accuracy, but, in fact, the olivine determination of Fa_{19} gives an indication of the composition of the pyroxene.

A lamellar pyroxene (cf. Tschermak 1885 Fig.58) is present in accessory quantity (Figure 9 B). Such lamellar pyroxenes show consistently low birefringence (first order greys) and high extinction angles, ranging up to 40 degrees. The lamellae may appear indistinct or well defined as in the grain illustrated (Figure 9 B). The consistently low birefringence and high optic angle observed are atypical of pigeonite. These grains seem to be orthopyroxene with exsolution lamellae. Such lamellae may be due to one of two causes (Deer, Howie and Zussman 1963 pp.15-26): gliding under stress, or exsolution of a calcic clinopyroxene in very narrow bands (Schiller inclusions). It is known that the former mechanism does apply to some meteorites (e.g. Shallowater achondrite; Deer, Howie and Zussman 1963 p.32). Some site is nevertheless required for the normative calcium silicate always revealed on chemical analysis of chondrites (it has always been the custom to put such calcium silicate in bronzite in meteorite norm calculations—see comment, McCall and Jeffery 1964 p.41) and the existence of cryptic Schiller inclusions has always seemed to resolve this anomaly in a most satisfactory manner. Similar lamellar orthopyroxenes are evident in the Narctha (McCall and de Laeter 1965) and Dalgety Downs (McCall 1966) chondritic stones and it is clear that they are by no means uncommon in olivine-bronzite and olivine-hypersthene chondrites. B. H. Mason (written communication) considers this lamellar-twinned pyroxene to be pigeonite (*sensu lato*). Recent

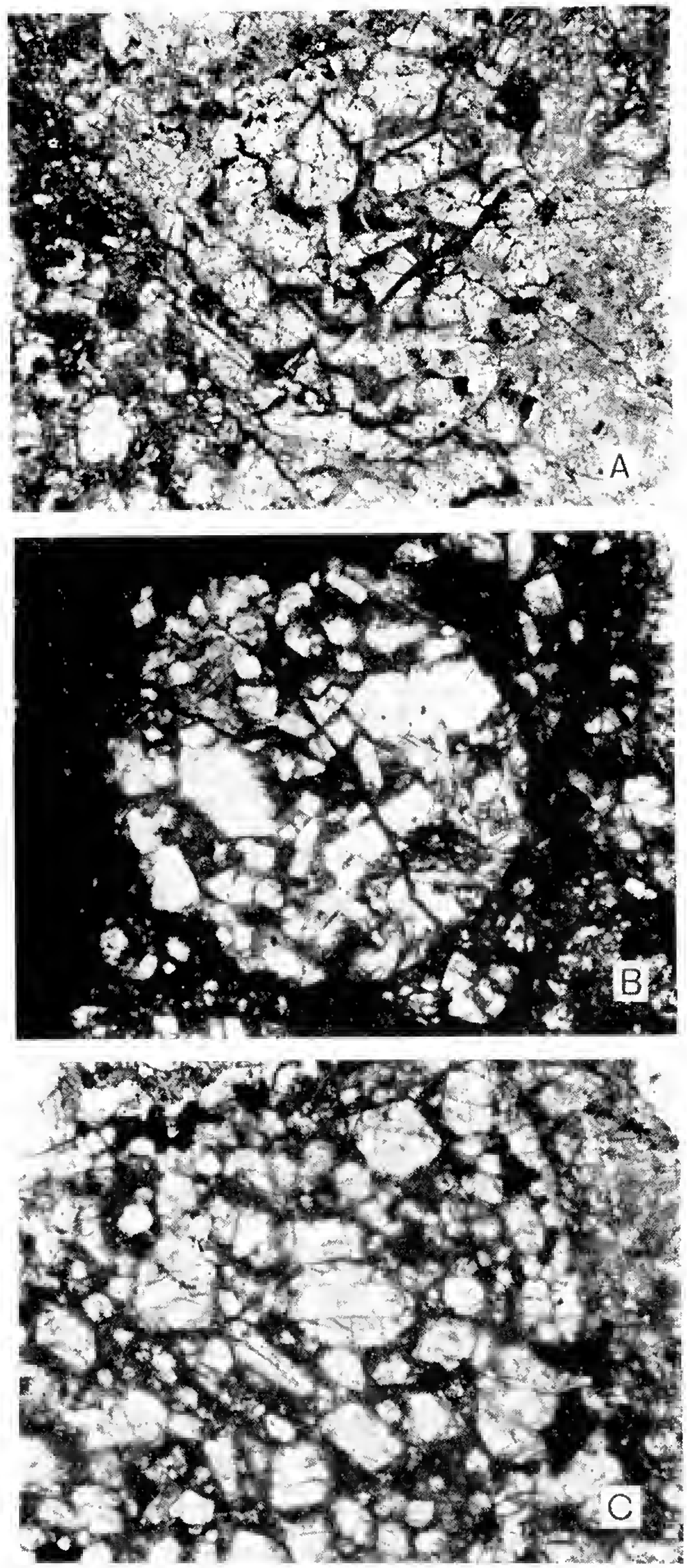

Figure 8. A.—Microporphyritic chrondrule containing subhedral olivine crystals (but showing gable terminations) in a base of devitrified glass; the fragmental inter-chrondrular matrix also shows up well in this photograph (x40, plane polarised light). B.—A similar microporphyritic olivine chrondrule showing euhedral olivine crystals set in a translucent glass base (grey), istotropic under crossed nicols. The peripheral matrix material surrounding this chondrule seems to be of amorphous material, probably iron oxide stained glass (x40, plane polarised light). C.—A similar vitrophyric chondrule shown under even higher magnification, at which the interstitial material still shows no resolution into discrete grains. It is translucent, though staining makes it appear mottled grey in the photograph. Under crossed nicols it is fully isotropic (x65, plane polarised light).

X-ray diffraction studies of pyroxene concentrates from chondrites show it to be present in appreciable amounts in practically all chondrites. It had been previously overlooked in optical studies of refractive indices because of the practice of selecting clear, coarsely crystallised orthopyroxene grains and neglecting the turbid, finely-crystallised clinopyroxene grains. Much of the normative plagioclase in chondrites may actually be combined in this pigeonitic clinopyroxene.

Plagioclase could not be identified and it must be assumed that the plagioclase (oligoclase) component always present in chondrite norms, is here locked up in the glass fraction.

Glass. There is true glass evident in the interstices of some of the microporphyritic olivine chondrules (which are more correctly termed microvitrophyric) (Figure 7, B and C). It is clove-brown coloured and translucent, appearing completely isotropic, though in other chondrules the interstitial glass appears slightly turbid, and largely anisotropic, indicating some degree of devitrification (Figure 7 A). B. H. Mason (written communication) now recognises that interstitial glass such as this is a fairly common feature of chondrules in highly chondritic meteorites. Metamorphism and recrystallisation which has affected many chondrites results in disappearance of this glass by devitrification and crystallisation. Microprobe analyses of such glass shows that its composition resembles that of oligoclase, indicating that it is probably the occult feldspar in these glass-containing chondrites. He further suspects that solid state recrystallisation (metamorphism) produces the orthopyroxene from the clinopyroxene, with the plagioclase separating from the Ca, Na, Al in the clinopyroxene. Such a process would explain the prominence of lamellar-twinned pyroxene, and paucity of oliclase in these highly chondritic chondrites, devoid of evidence of metamorphism, and the abundant recrystallised plagioclase and paucity of clinopyroxene in highly recrystallised chondrites such as Woolgorong (McCall and Jeffery 1964).

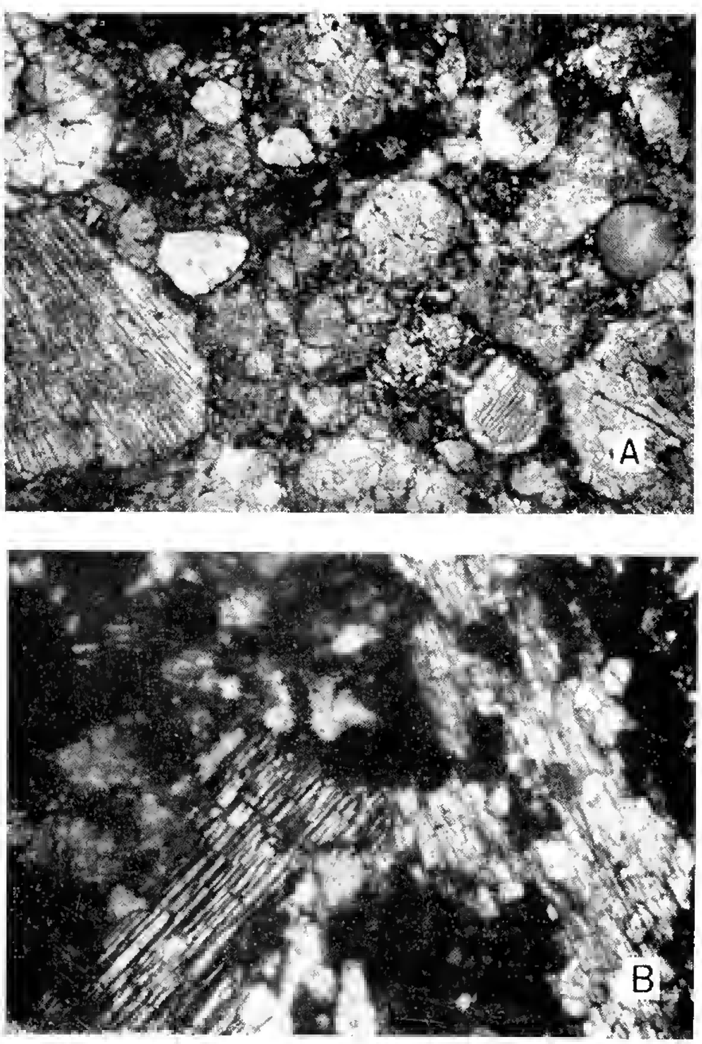

Figure 9. A.—A monosomatic barred olivine chondrule with an annular rim is evident (lower right). The more common excentric fan chondrules are seen (left and middle, right). The former is coarsely crystalline and not preserved in its entirety, being broken: the latter is ultrafinely fibrous (x40, plane polarised light). B.—Lamellar pyroxene in a position of extinction of the exsolution lamellae (cross hairs parallel to margins of photograph) (x105, crossed nicols).

Mode. An approximate mode for the fresh meteorite has been visually estimated:—

	%
Olivine	35
Orthopyroxene (including lamellar grains)	45
Nickel-iron (kamacite) plus troilite	15
Glass	5

X-ray Diffraction Studies

Olivine. Using the method of Yoder and Sahama (1957), olivine from this meteorite was identified as Fa_{19} (analyst B. H. Mason). This provides the clearest evidence that it is an olivine-bronzite chondrite of Prior's class 2 (Mason 1963). It is, indeed, very similar to the Selma meteorite, figured by Mason, (1962 p.90), but reveals slightly less interstitial material and a slightly higher degree of brecciation. As in the Selma meteorite, advanced oxidation under atmospheric conditions precludes full chemical analysis.

Orthopyroxene. The inference may be drawn that the orthopyroxene is about Fs_{18} since orthopyroxenes take up slightly less of the iron slicate molecule than the olivines.

Glass. The microbotryoids were crushed and an X-ray diffraction photograph obtained from the powder. This was carried out in order to establish the nature of the anisotropic, fibrous material in the fusion crust. The picture obtained suggests that the material is a mixture of amorphous material and γ-ferric oxide (maghemite).

Conclusions

This new find poses some interesting problems:—

(a) The fusion crust shows hexagonal plates. This feature does not appear to be recorded in the literature, and requires explanation.

(b) The largest of the contained chondrules, with their two-fold composite character present a problem of mode of formation, one that must be answered before any hypothesis of chondrule formation can be regarded as a reasonable theory. It may be naïve for the geologist to ask this question, but can such patterns within chondrules be reasonably equated with Wood's hypothesis (1963 p.382) of condensation within

the gaseous nebula prior to the formation of the solar system? Could such a complexity develop from matter in a primordial state, in which the necessary degree of heterogeneity is surely not to be expected?

(c) The existence of clear glass in some chondrules cannot be denied. Such an occurrence has some relevance to studies of devitrification, so important to vulcanologists. An occurrence of glass of Precambrian age in terrestrial rocks has been reported (975 m.y; Philpotts and Miller 1963) suggesting that something more than mere passage of time is required for devitrification to occur. The great age inferred for chondrule formation from isotropic evidence combined with the presence of true glass suggests that meteorites are insulated from the agencies, which, with the passage of time, almost inevitably act to devitrify terrestrial glasses.

Of more local interest is the fact that this discovery represents the first one made close to the West Australian coast. It was noted during the compilation of a catalogue of meteorite occurrences in this State (McCall and de Laeter 1965) that there was a complete blank in the coastal areas, contrasting with the numerous discoveries inland. The discovery of this deeply weathered stone supports the belief that sea air, being particularly destructive to nickel-iron masses, militates against any long term preservation of stony meteorites or irons in the coastal areas, while stony masses may be preserved for centuries in the arid interior of the State. In the coastal finds deep weathering cannot be taken as indicative of a long terrestrial history—the lack of any record of a fireball and related phenomena in the district is of no significance in view of the low population density. The Frenchman Bay meteorite may be a comparatively recent fall, not more than a few years ago.

Acknowledgements

To the acute observation and interest displayed by Mr R. L. Devitt and Mr J. H. Turner we owe this discovery, and their generosity in presenting the meteorite to the Western Australian Museum must be acknowledged. Dr. B. H. Mason assisted the writer with X-ray diffraction determination of the olivine and Mr J. R. de Laeter investigated the fusion crust using similar techniques. Technical work in support of this investigation was carried out by Mr W. Smeed and Mr K. C. Hughes (photographer). The line drawings used in Figures 1 and 3 were drafted by Miss Rosemary Hunt and the drawing of the fusion crust used in Figure 6 was made by Miss Robin Peers.

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7.—The Dalgety Downs chondritic meteorite

by G. J. H. McCall*

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Abstract

The Dalgety Downs meteorite is now known to have been erroneously described some twenty years ago as a stony iron. A large amount of new material lately recovered from the site of the original find shows it to have the character of an olivine-hypersthene chondrite. A full description is given here, and some unusual features are mentioned—the deformation structure, the unusually large individual hypersthene chondrule, and the lamellar twinned pyroxene.

Introduction

The Dalgety Downs meteorite is recorded by Prior and Hey (1953 p.97-98) as a stony-iron (fine grained siderolite), and by Mason in a list of mesosiderites, together with Bencubbin (1962 p.122). While Bencubbin is a stony-iron meteorite but not a mesosiderite (Lovering 1962; McCall and de Laeter 1965), there is now no doubt that Dalgety Downs is a common chondrite. The error seems to be due to a mistaken practice of referring to any meteorite containing both silicate and iron as a stony iron, irrespective of the proportions.

Interest in this record was revived early in 1963, when Dr. B. H. Mason of the American Museum of Natural History sought information from the Director of the Western Australian Museum concerning this and three other "lost" meteorites recorded by Prior and Hey (1953). Enquiries were started and a trace of the actual material reported in 1942 (Anon.) was discovered in the form of a small, iron-stained chip in the collection of the Government Chemical Laboratories, Perth. With surprise it was noted that this chip had the characteristics of a chondrite, and thin section study confirmed this view.

In July 1963 two further developments occurred. The writer was shown a specimen of 3.3 lbs weight in the collection of the School of Mines, Kalgoorlie. This was labelled "Ashburton Downs" (the name of a sheep station to the north of Dalgety Downs). A portion of this material had been removed by H. H. Nininger in an exchange transaction and from this B. H. Mason had already determined the olivine as Fa_{25} (Mason 1963 p.1014). During this same month Dr Mason and Mr. E. P. Henderson of the Smithsonian Institution, Washington, were directed to the site by the actual finder and recovered nearly five hundred pounds of fragments. Comparison of this new material with that labelled "Ashburton Downs" revealed an astonishing similarity, in chondritic structure, fracturing and veining, and orientation of the metallic flecks. It was so marked that coincidence seemed improbable, and the possibility that Ashburton and Dalgety Downs were one and the same meteorite was suggested. Confirmation came shortly afterwards when it was discovered that some fragments known to come from Mount Egerton (Prior and Hey 1953 p.248; McCall, 1965) had been wrongly labelled at the Kalgoorlie School of Mines: and, in the same register that accession of these fragments had been recorded, was found the record of accession of a specimen identical with that labelled Ashburton Downs, but entered as "from Mr. P. A. Healy, Dalgety Downs". As Mr. Healy has been associated with but the one find, and there is no trace of any other material of this nature in the collection, it seems reasonable to assume that the faulty recollection of some

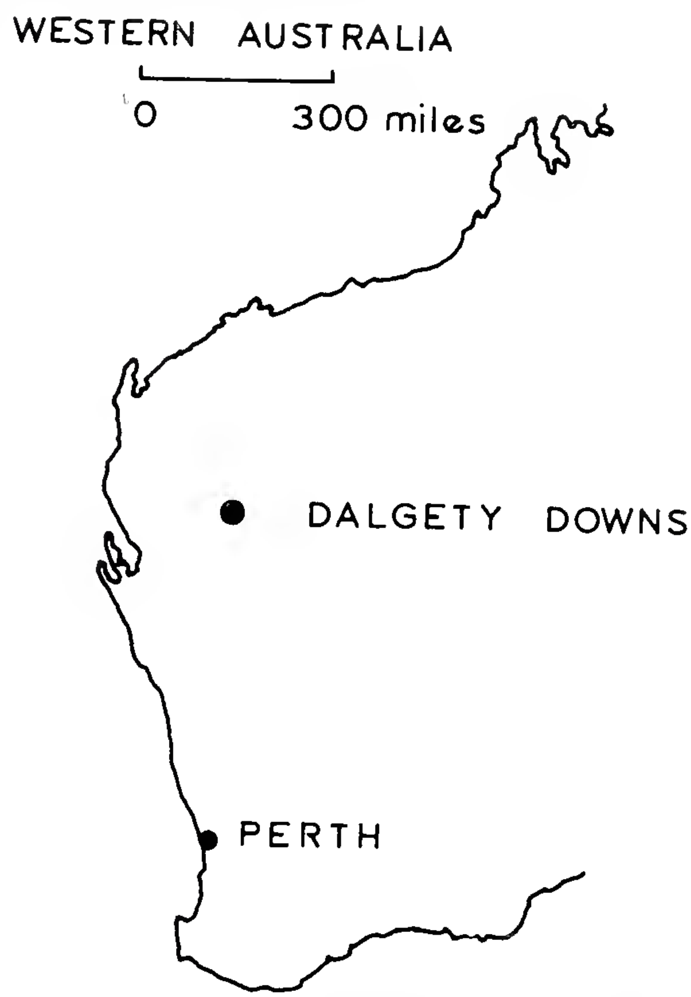

Figure 1.—Location of the Dalgety Downs meteorite recovery.

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person unknown when labelling the specimens some time after accession (it was wartime and strict routines had probably lapsed), allowed the name Ashburton Downs to enter the literature. It should now be regarded as nothing more than a synonym for Dalgety Downs.

In June 1964 Mr. W. H. Cleverly, Head of the Geology Department, School of Mines, Kalgoorlie and curator of the Kalgoorlie collection, visited the site and made a sketch of distribution

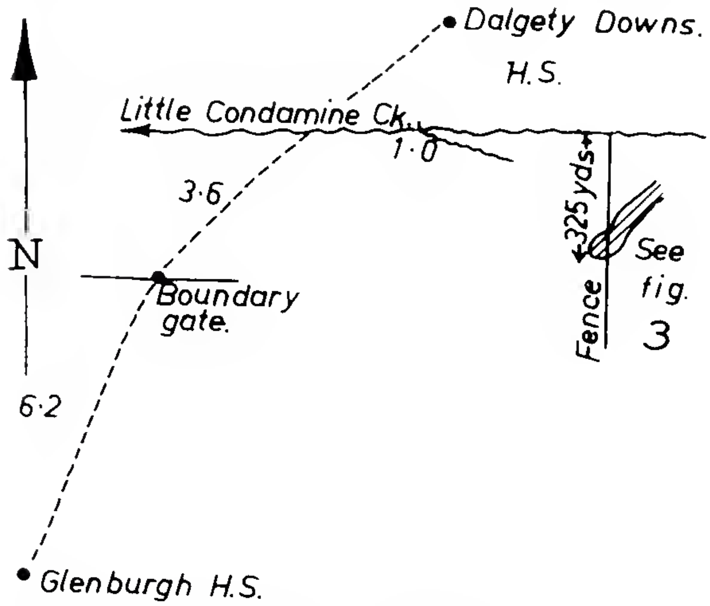

Figure 2.—Location of the Dalgety Downs meteorite recovery. The figures show distances in miles.

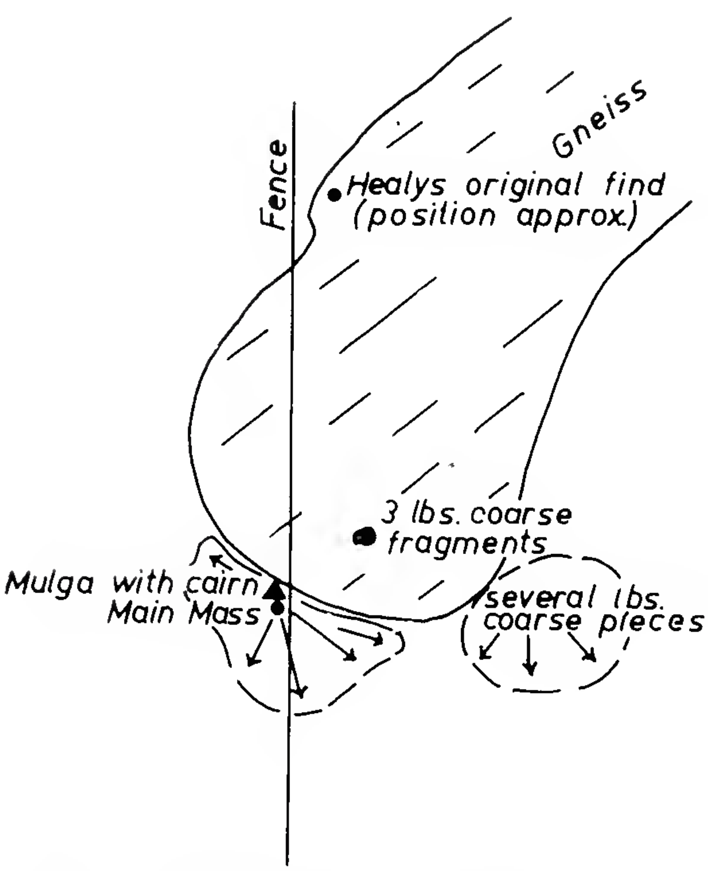

Figure 3.—Enlargement of part of Figure 2, showing details of recovery locations.

of fragments from his own observation and that of the finder, Mr. Healy, who accompanied him. His sketch, which is reproduced in Figures 2 and 3, is accepted as correct by Dr. Mason (written communication) who, however, adds that he found some outlying fragments up to 150 yards from the main mass. Mr. Cleverly recovered a further 90 lbs of fragments, all that he could transport, and believes that still more remain on the ground. The total recovery to date is:—

a "Dalgety Downs", Healy recovery	Government Chemical Laboratories, Perth—small chip
b "Ashburton Downs", Healy recovery	School of Mines, Kalgoorlie, Western Australian Museum University of Arizona, Tempe, American Museum of Natural History, British Museum, Natural History—8 lbs.
c "Dalgety Downs", Mason and Henderson recovery	Western Australian Museum —9 lbs, American Museum of Natural History: Smithsonian Institution, Washington—472 lbs.
d "Dalgety Downs", Cleverly recovery	School of Mines, Kalgoorlie—90 lbs.
	Total—c. 579 lbs

The recovery of approximately 579 lbs of material makes this the largest recovery of stony meteorite material in this State and the second largest such recovery in Australia; and how much additional material remains out at the site is not known.

The find

The position of the find is about three miles south by east of the homestead of Dalgety Downs sheep station in the Gascoyne District of Western Australia: Latitude 25° 21' South; Longitude 116° 11' East (Fig. 1). The find was made in 1941 and Mr. P. A. Healy, the finder, believed that he had picked up some terrestrial rock detritus and was most surprised to learn of its true nature. Dr. Mason reports that even he and Mr. Henderson did not immediately recognise the brownish, weathered material scattered over the surface as the meteoritic material they sought, for it had the appearance of lateritic float material all too familiar in this State.

The distribution of the fragments on the ground (Figs. 2 and 3) suggests a flight trajectory bringing the meteorite in from the north-north-west. None of the fragments was appreciably buried.

Most of the material recovered by Mason and Henderson was part of a single conical mass which fell apart into a mass of fragments as it was excavated. The point of the cone was downwards, and the mass was evidently in the position of fall. Original surface showing regmaglypts was present on all buried surfaces, but the part level with the ground surface was broken and fragmentary. It appears probable that the meteorite landed as a single mass and the impact caused shattering and the distribution of small fragments around the main mass; this distribution may have been modified into a more widespread pattern by the agency of sheet flood erosion consequent on the occasional extremely heavy rains which are a feature of the local climate.

Figure 4.—Large fragment (Wt. 11 kg) showing regmaglypts. (No.41388 American Museum of Natural History Meteorite Collections.) (Photo American Museum of Natural History).

Figure 5.—Large fragment (Wt. 59 kg) showing elongated regmaglypts. A white caliche encrustation covers the bare surface of the stone; in spite of the regmaglypts there is no fusion crust preserved. (No.4189 American Museum of Natural History Meteorite Collections.) (Photo American Museum of Natural History).

Physical properties and surface features

The individual fragments range from a foot or more across to pebble size. All have a deep ferruginous weathered surface layer and in many this extends right through the mass. However, on cutting, some of the larger masses reveal relatively fresh, greenish core material (Fig.6). There is not a trace of fusion crust and one must assume that it has decomposed and flaked off during a long period of exposure to the terrestrial atmosphere—otherwise there is no reason why it should not be present since some of the surfaces of the larger masses are original ablation surfaces, revealing distinct patterns of regmaglypts (Figs. 4 and 5). The distribution of fragments on the ground and the relation of ablation—marked surfaces to secondary surfaces suggests that the mass fractured and disinte-

grated very late in its atmospheric flight, either just before impact as the preceding compression wave rebounded off the ground or at the moment of impact. The latter seems much more likely, but there is no certainty that it was a single mass; attempts to reconstruct the mass in the same manner as the Woolgorong stony meteorite (McCall and Jeffery 1964) would be quite futile considering the number of fragments and their weathered state.

Many of the masses are coated with creamy white calcareous caliche (Fig. 5), due to the action of surface water.

The specific gravity of the fresh core material is 3.50, a figure quite typical of this class of meteorite (Average 3.51; Mason 1962 p. 95).

No normal-sized chondrules show up to the naked eye on fresh surfaces (Fig. 6), but rounded and distorted chondrules are apparent on cut faces of weathered specimens. One giant chondrule (diameter 1.0 cm) does however show on the cut face of the specimen formerly labelled "Ashburton Downs" and sub-parallel aligned nickel-iron and troilite flecks are apparent on most fresh cut surfaces (Fig. 6). The inconspicuous nature of the chondritic structure seems to be due to secondary brecciation and overall fineness of texture rather than to recrystallisation processes.

Microscopic examination

As with many fine-textured meteorites the examination of the gross texture is best carried out with a binocular microscope using oblique reflected light. The deformation texture so observed is most interesting; it has been noted above that nickel-iron and troilite specks appear to the naked eye to possess a sub-parallel orientation, and with increased magnification the nature of this deformation structure becomes apparent. The mass is traversed by sets of hair-line fractures which, in certain areas, are very closely spaced, while in othe areas they are not conspicuous. In the vicinity of close concentrations of such fine cracks the chondrules are broken and deformed into ellipsoids (Fig.7A), while the nickel-iron and troilite tends to form compound aggregates or discrete specks aligned roughly parallel to the cracks. The troilite tends to be associated with the nickel-iron aggregates as subordinate specks or partial rims (Fig. 8A and B), the latter relationship suggesting that it was crystallised later than the nickel-iron. Careful examination shows that the troilite actually fills the cracks as thread-like veinlets or shows marked concentration round intersections of cracks (Fig. 8 A). The nickel-iron has suffered displacement on some cracks which are in fact microfaults (Fig. 8 C), but, though nickel-iron aggregates are elongated in a sub-parallel manner due to deformation under stress, it does not, in contrast to the troilite, infill the cracks as a later veining material.

This fabric seems to be related to two principal sets of fractures and indicates that the meteorite suffered some form of directed stress, and that not so late in its history that troilite could not be mobilised and recrystallised along the fracture lines. It is generally accepted that such troilite crystallisation would not occur during the period of atmospheric ablation which usually results only in thin intrusions of glass veining the body of the meteorite, projections of the fusion crust (McCall and Jeffery 1964 p.36). However the remote possibility of troilite recrystallisation during ablation cannot be dismissed outright since there is evidence of possible recrystallisation of troilite in the fusion crust of another Western Australian meteorite (Frenchman Bay: McCall 1966). Yet the size of the Dalgety Downs mass seems against any such effect and we can reasonably conclude that we are seeing the results of fracturing and recrystallisation during a period of stress or shock suffered by the rock mass within the parent cosmic body before the meteorite was isolated in the relatively small fragment of that body which eventually encountered the Earth. It is a type of directed texture quite different from those lately discussed by Dodd (1964), those being primary penetrative textures related to "deposition", not secondary deformation. This texture qualifies the Dalgety Downs meteorite for the description "unevenly veined and brecciated" but does not appear to be in any way related to "deposition".

Under reflected light the glass areas contrast strongly with the ore minerals, showing pale brown and non-reflectant, and it is clear that there is appreciable glass in this meteorite though much of it is turbid and near-opaque, due to devitrification.

Figure 6.—Dalgety Downs; cut section showing sub-parallel orientation of metal flecks and a giant hypersthene chrondrule—(W.A.M. No.12173 x1.2).

Thin section examination shows again, the patchy distribution of deformation. In some areas the chondrules preserve their spherical form (Fig. 7 B). The tendency for ore minerals and ironstained amorphous material (after glass?) to swathe chondrules is apparent (Fig. 7 B) though not so obvious as in some not-recrystallised chondrites.

The silicate minerals of the chondrules include *olivine,* present in the form of euhedral or subhedral crystals and aggregates without crystal outlines (e.g., in barred chondrules); *hypersthene* present in subhedral grains and fibrous aggregates; and rare grains of a *lamellar-twinned pyroxene* similar to that described and figured by Tschermak (1883 Fig.58). The indistinctness of the lamellae and (Fig.9A) stronger positive relief distinguish this mineral from plagioclase. The extinction angle of the lamellae is about 40°. B. H. Mason (written communication) considers this to be a pigeonitic clinopyroxene (see McCall 1966 for discussion). Modal oligoclase cannot be detected with any confidence in this meteorite by normal microscopic methods and one must conclude that in these glassy chondrites it is represented in the glass component (and possibly some of the anorthite is represented in the pigeonitic pyroxene), for normative plagioclase is always apparent in chemical analyses (McCall and de Laeter 1965 p. 30-32) and in much the same amount as in strongly recrystallised chondrites such as Woolgorong (McCall and Jeffery 1964), in which crystalline felspar is abundantly apparent. However there is some finely granular material, of very low birefringence and refractive

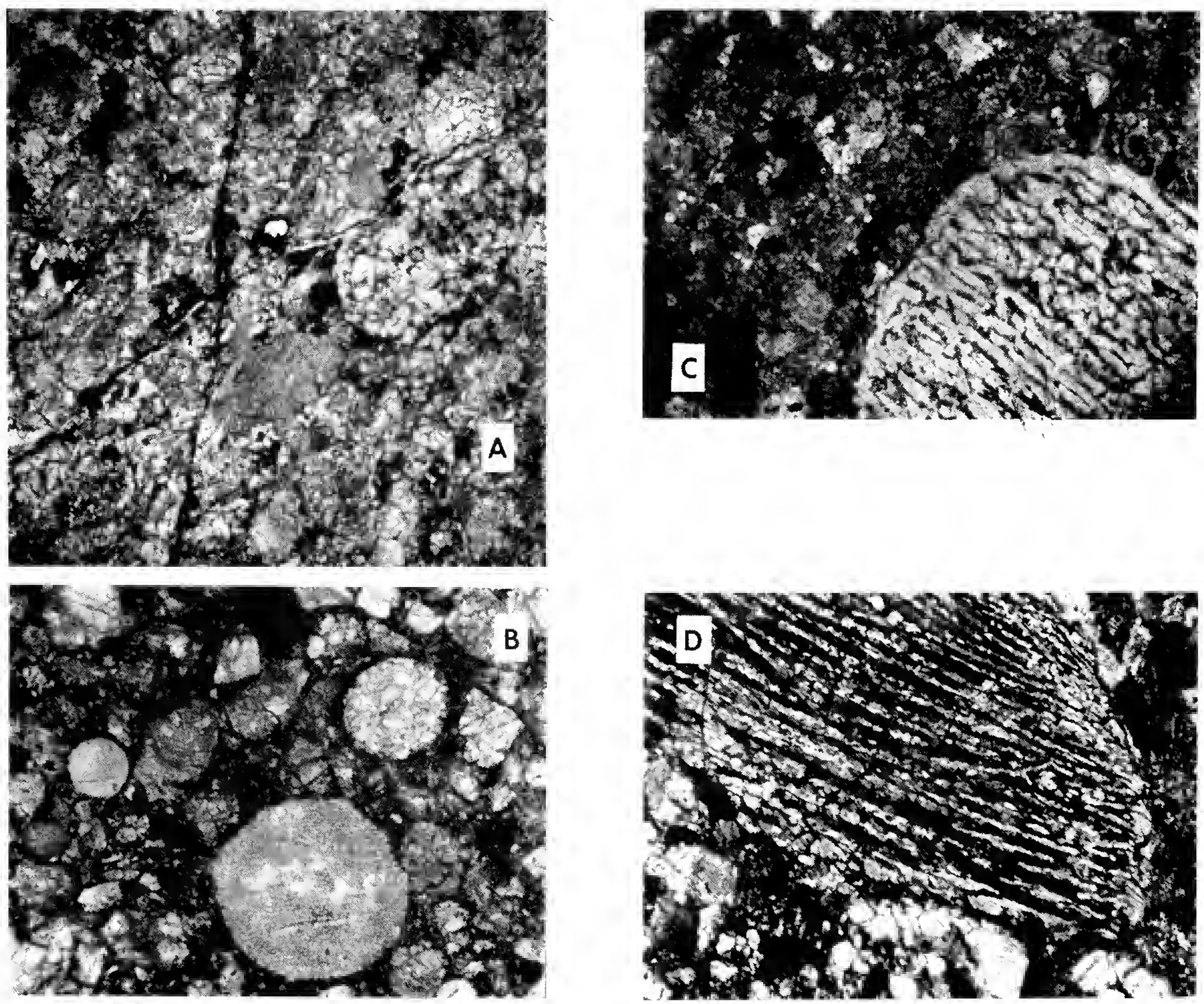

Figure 7.—A.—General view of the chondritic texture intersecting microfaults, with troilite (black) concentrated at the point of intersection and filling the veins. The ellipsoidal form of two chondrules, a fan chondrule and a granular chondrule (middle, right), suggests that the stress which caused the fracture also deformed the once spherical chondrules. (x6.2, plane polarised light). B.—Spherical chondrules in an area away from fractures, including a finely grated type (lower, centre), a cryptocrystalline fan chondrule of orthopyoxene (middle, left) and a microporphyritic chondrule containing interstitial glass, (upper right). (x16.5, plane polarised light). C.—Monsomatic barred chondrule with annular rim. This large chondrule contains crystalline material of low relief and low birefringence between the bars. (x16.5, crossed nicols). D.—Monosomatic barred chondrule. Olivine forms the bars as in all monosomatic varieties but there is interstitial granular material of low birefringence and low relief (although it is crammed with inclusions which give a deceptive appearance of high relief except under high power) (x40, crossed nicols).

index comparable with felspar, sparsely represented in the interstices between olivine and pyroxene grains (Fig. 9B) and in selvedge material of one large barred chondrule. It shows three cleavages at 60° to one another. It has not been identified. Mason (written communication) has made an acid insoluble concentrate from this meteoritic material, and detected some fine-grained plagioclase of mean refractive index 1.540 (An_{15}). The identification of this plagioclase has been confirmed by X-ray powder diffraction photograph. He has also used a microprobe to show that the glass in glass-containing chondrites is probably of felspar composition, closely resembling that of oligoclase.

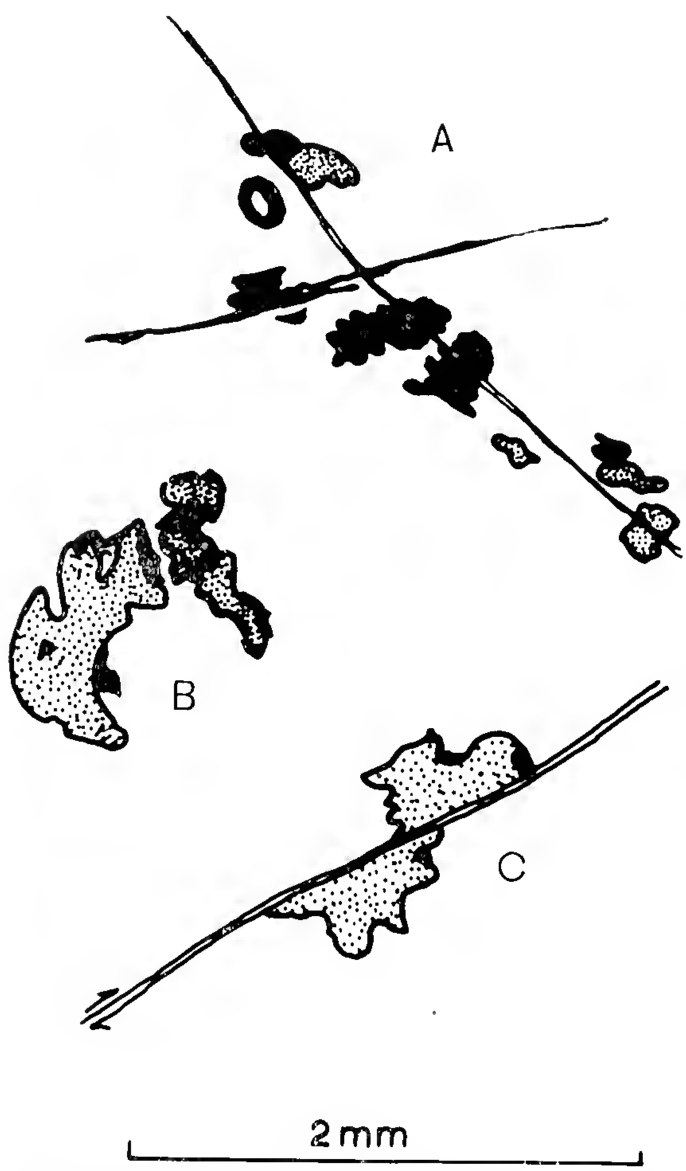

Figure 8. A.—Intersection of fracture planes showing concentration of troilite (black) near the intersection, and in the actual cracks, while kamacite (stippled) shows no such concentration. B.—Troilite (black) fringing kamacite (stippled). C.—Kamacite (stippled), fringed by troilite (black) and displaced by a microfault.

There is some translucent brownish glass within the chondrule interstices, though it is to some extent devitrified; most of the glass is completely devitrified.

Amongst the chondrules the following types are apparent:—

Monosomatic chondrules. These include chondrules formed of single crystals of pyroxene or olivine, mostly rather irregular chondrules showing no complexity of structure. Other monosomatic chondrules are formed of wide bars and narrow screens in the core, and a rim somewhat wider than the bars of the core (Fig. 7C). They extinguish in an undulose manner due to strain but are formed of a single crystal of olivine. The screens are mostly of glass or cryptocrystalline material after glass, but one large individual shows screens of finely-crushed olivine granules and the mineral of low refractive index and birefringence mentioned above (Fig. 7C). There is also present some irresolveable material which may be glassy or cryptocrystalline.

Polysomatic chondrules. Far more numerous than the monosomatic types, these include: granular aggregates of olivine or pyroxene alone, but with grains showing different orientation; aggregates of olivine phenocrysts set in glass or fine cryptocrystalline aggregates after glass (Fig. 7B); aggregates of pyroxene and olivine together, with or without interstitial glass or cryptocrystalline material; fan chondrules of olivine and, more often, orthopyroxene in slender fibres (both single excentric fans and compound aggregates of several fans in one chondrule are seen).

Among both olivine and orthopyroxene chondrules are some which show a finely-barred structure and include central cores of glass or cryptocrystalline material (Fig. 7C). There are also some finely barred chondrules composed of an olivine grid in optical continuity, and separated by granules of a weakly birefringent mineral with different orientation and peppered with minute droplet inclusions (Fig. 7D). These may be pyroxene or may be the unidentified mineral mentioned above. A most unusual feature is the giant chondrule (Fig. 9C; McCall and de Laeter 1965 Plate XIXa), composed of granular hypersthene; its oval outline seems to indicate that it is a chondrule not an achondrite enclave.

There is no significant evidence of recrystallisation except the partial or complete development of granules instead of glass in some barred chondrule selvedges, and the anisotropic (cryptocrystalline) character of most of the interstitial material that once was glass, and is now in varying stages of devitrification. It would seem fair to assess this as a chondrite showing considerable devitrification but no significant recrystallisation to obliterate the chondrules.

Modal composition

The mode was measured using a graticule on both reflecting surface and thin section, with the following result:—

Nickel iron, plus troilite	8-10%	(kamacite/troilite 3/1)
Silicate	90-92%	

Approximate silicate composition: olivine 65%; orthopyroxene (hypersthene) 25%; clinopyroxene—trace in schiller inclusions; unidentified mineral of low refractive index-trace; glass 2% (mostly devitrified).

These measurements are, of course, very approximate due to the variable nature of the material.

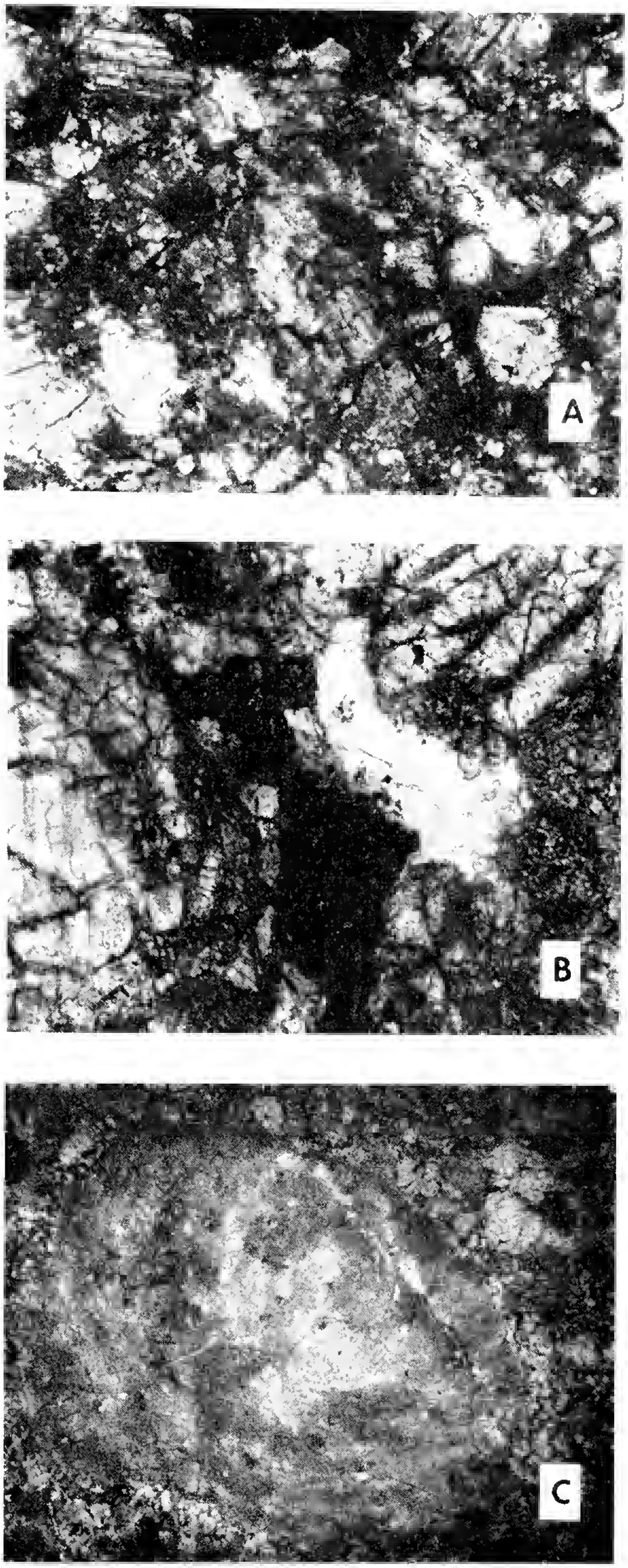

Figure 9.—A.—Lamellar pyroxene grain, (x63, crossed nicols). B.—Pool of a mineral of low relief and birefringence, appearing like untwinned felspar but showing anomalous cleavages (x63, plane polarised light). C.—Giant orthopyroxene chrondrule (x6.3, plane polarised light).

Chemical analysis

A full chemical analysis was carried out by Dr. A. A. Moss at the British Museum, Natural History, London, and is reproduced by McCall and de Laeter (1965 p.30-32). The following ratios derived from this chemical analysis:—

(a) Molecular MgO/FeO 3.55 (bulk; 1/7 in magnetic fraction).

(b) Nickel/iron = 1/6.57.

place this stony meteorite within Prior's class 3—(olivine-hypersthene chondrites). This was confirmed by X-ray diffraction using the method of Yoder and Sahama (1957), values obtained for the olivine being:—

Dalgety Downs (Ashburton Downs)—Fa_{25} (Determined by B. H. Mason, American Museum of Natural History).

Dalgety Downs (Mason and Henderson—Fa_{24} recovery) (Determined by B. H. Mason, American Museum of Natural History).

These are typical values for olivine in olivine hypersthene chondrites (Mason 1963).

Acknowledgements

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8.—The largest known dumbbell-shaped australite

by George Baker*

Manuscript received 18 May 1965; accepted 22 June 1965.

Abstract

The largest known dumbbell-shaped australite, discovered in 1960 near Cuballing in Western Australia, is the longest, and the fourth heaviest, australite recorded. It is 100 mm long, weighs approximately 176 grams, and is further evidence than most of the larger and heavier australites occur in the western parts of the Australian tektite strewnfield. The sculpture pattern of the specimen is dominated by pits and grooves resulting from natural solution etching in a terrestrial environment. There are no clearly recognizable remnants of the outer aerodynamically heated skin that is developed on australites during their hypersonic passage earthwards through the atmosphere.

Introduction

A large australite of somewhat irregular dumbbell shape has been kindly lent by J. H. Lord, Director of the Geological Survey of Western Australia, for purposes of description. The specimen was brought to notice by Mr D. Jackson, whose father discovered it in 1960 on a property near Cuballing, north of Narrogin, Western Australia. Cast replicas are lodged in the collections of the Western Australian Museum (12323) and the Geological Survey of Western Australia (R2024). Cuballing (117°5'E; 32°51'26"S) is approximately 96 miles southeast of Perth. The specimen was found at the surface on a ridge in a paddock which had been ploughed.

Its shape is nearest to that of the more regularly dumbbell-shaped australites. Although the waist region is not as marked as in most other australite dumbbells, it is nevertheless distinct to the eye and to the touch, and the two gibbosities on either end of the waist region are of somewhat different dimensions (Fig. 1).

Size of the specimen and the relationship of its size and weight to that of other large australites

The specimen is 100 mm long. Its width ranges from 42.0 mm across the larger gibbosity to 35.8 mm across the smaller gibbosity, the depth (= thickness) measurements for which are 33.7 mm and 25 mm respectively. Its weight of nearly 176 grams makes this dumbbell-shaped form the fourth heaviest of the known large australites.

Thirteen australites that each weigh over 100 grams (Fenner 1955; Baker 1961, 1962, 1963) are at present known. Of these, only three weigh over 200 grams: from Warralakin, W.A., Lake Yealering, W.A., and Karoonda, S.A. The elongated australite from Cuballing, W.A., now replaces the round australite core from Graball, W.A. (Baker 1963) as the fourth heaviest australite known (see Table 1). The total weight of the thirteen specimens is approximately 1,972 grams.

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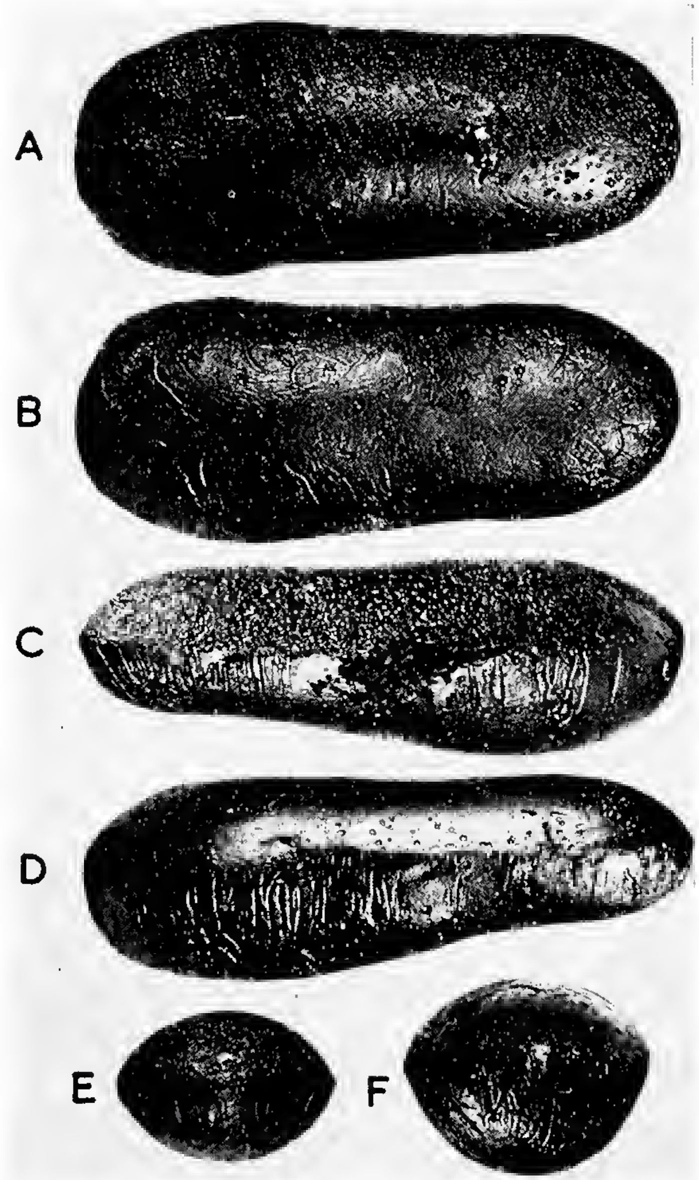


Figure 1.—Largest known dumbbell-shaped australite, Cuballing, Western Australia. A.—Posterior surface showing fine flow lines and surficial pits of variable distribution density. B.—Anterior surface showing gutters and surficial pits; the pits tend to be fewer but somewhat larger generally than on the posterior surface. C.—Side aspect (posterior surface uppermost) showing rim delineating posterior and anterior surfaces; maximum etching has occurred in the region of the rim (darker regions in centre of photograph). D.—Opposite side aspect (posterior surface uppermost) to that in C. Fewer pits are revealed on the posterior surface compared with C; gutters in the equatorial regions of the anterior surface are equally as marked as in C. E.—End-on aspect of smaller gibbosity, showing pits on posterior surface and gutters on anterior surface. F.—End-on aspect of larger gibbosity, showing fewer pits on right-hand side of posterior surface and well developed gutters on anterior surface. For dimensions see text. (Photographs by R. K. Blair.)

As received, hand lens inspection of the Cuballing specimen revealed that about two dozen of the surficial pits contained soil constituents partially cemented on to the pit walls. Before weighing the specimen in air and in deionized water for specific gravity determinations, these adventitious constituents were largely removed by immersing the specimen in 1:1 HCl in a beaker placed in an ultrasonic vibrator. One effect of the removal of the soil constituents was to reveal the rather high degree of lustre of the pit walls compared with the surrounding glass of the tektite surface.

Table 1 shows that the dumbbell-shaped australite from Cuballing is the longest form (100 mm) on record among the heaviest australites. Furthermore, there are no elongated specimens of more slender character weighing under 100 grams that measure anywhere near 100 mm.

Although the Cuballing specimen is 18 mm longer than the heaviest known elongated australite (from Karoonda, S.A.; see No. 3, Table 1) it is significantly narrower (by nearly 5 mm as a minimum) and thinner (by approximately 4 mm as a minimum), and is hence lighter in weight by almost 33 grams.

TABLE 1

Dimensions and weights of the known australites weighing over 100 grams

No.	Shape type	Locality of discovery	Size measurements* (mm.)	Weight (gms.)	Specific gravity	Reference
1	Oval core	Warralakin, W.A....	70 (65) x 62·5 x 42	238 (approximately 265 gms. allowing for piece artificially spalled off)	2·409	Baker, 1962 (Plate I, Figs. A to D).
2	Round core ...	Lake Yealering, W.A.	64 x 64·5 x 39·4	218	.	Fenner, 1955 (Plate VII, nos. 1 & 2)
3	Boat (abraded)	Karoonda, S.A.	82 x 46·8 x 37·9	208·9	..	Fenner, 1955 (Plate VII, nos. 3 & 4)
4	Dumbbell	Cuballing, W.A.	100 x 42 (35·8) x 33·7 (25)	175·996	2·435 (T_{H_2O} = 23·1° C)	(this paper)
5	Round core	Graball, W.A.	57 x 34·5	168·28	2·434	Baker, 1963 (Plate I, Figs. A & B)
6	Oval core (chipped)	Western Australian Goldfields	51·5 x 48·5 x 43	154·3	....	Fenner, 1955 (Plate VII, nos. 5 and 6)
7	(not given)	Corrigin, W.A.	(not given)	147	....	Fenner, 1955 (not illustrated)
8	(not given)	Lake Buchanan, W.A.	(not given)	116	...	Fenner, 1955 (not illustrated)
9	Round core (slightly oval from weathering)	Between Karoonda and Lowalda, S.A.	52·1 x 51·5 x36·5	113	.	Fenner, 1955 (Plate VII, nos. 7 & 8)
10	Broad oval	Babakin, 170 miles E. of Perth, W.A.	52 x 46 x 37·5	112·9	...	Fenner, 1955 (not illustrated)
11	Round core (slightly oval from weathering)	Norseman, W.A.	51·1 x 50·5 x 33·1	111	...	Fenner, 1955 (Plate VIII, no. 14)
12	Boat	Narembeen, W.A....	64 x 37 x 30·5	107·457	2·431	Baker, 1961 (Plate I, Figs. A to E)
13	Oval core	Karoni, W.A. ...	49·1 x 45·5 x 35·5	101		Fenner, 1955 (Plate VIII, nos. 15 & 16)

* The size measurements are given in the order : length, width, depth (= thickness), for the elongated examples ; and in the order : diameter, depth, for forms that are round in plan aspect. Numbers given in brackets are the lowest values for ranges in width and depth for specimens (such as the Cuballing example) having maximum and minimum width and depth values arising from departures from the more regular shape types.

It is notable that of the thirteen largest and heaviest australites placed on record (Table 1), 85 per cent have been discovered in Western Australia at the western end of the 2,000-mile long tektite strewnfield, 15 per cent come from the south-central portion of the island continent, while none weighing over 100 grams are yet known from the eastern States of Australia.

Arcs and radii of curvature of the surfaces

In planes normal to the long axis of the specimen and through the thickest portions of the larger and smaller gibbosities, silhouette traces of the curved posterior surface (top surface in Fig. 1 C-F) and anterior surface (bottom surface in Fig. 1 C-F) were found to fit closely the arcs of curvature of circles constructed about these surfaces. For these surfaces, the radii of curvature (R_B and R_F) were determined graphically with the results shown in Table 2.

TABLE 2

Radii of the arcs of curvature across the width of posterior and anterior surfaces for the larger and smaller gibbosities respectively

	Larger gibbosity	Smaller gibbosity
R_B (mm.)	23·0	20·0
R_F (mm.)	20·0	20·0

R_B = radius of curvature of posterior (back) surface.
R_F = radius of curvature of anterior (front) surface.

From Table 2 it is seen that whereas the original radius of curvature of each gibbosity, as given by the R_B values, differed by 3 mm, the ultimate radius of curvature of the anterior surface, as given by the R_F values, become the same. This was evidently largely a consequence of aerodynamic ablation of the surface facing down the flight path during hypersonic transit through the earth's atmosphere, rather than a result of subsequent spallation and natural solution while resting on the earth's surface.

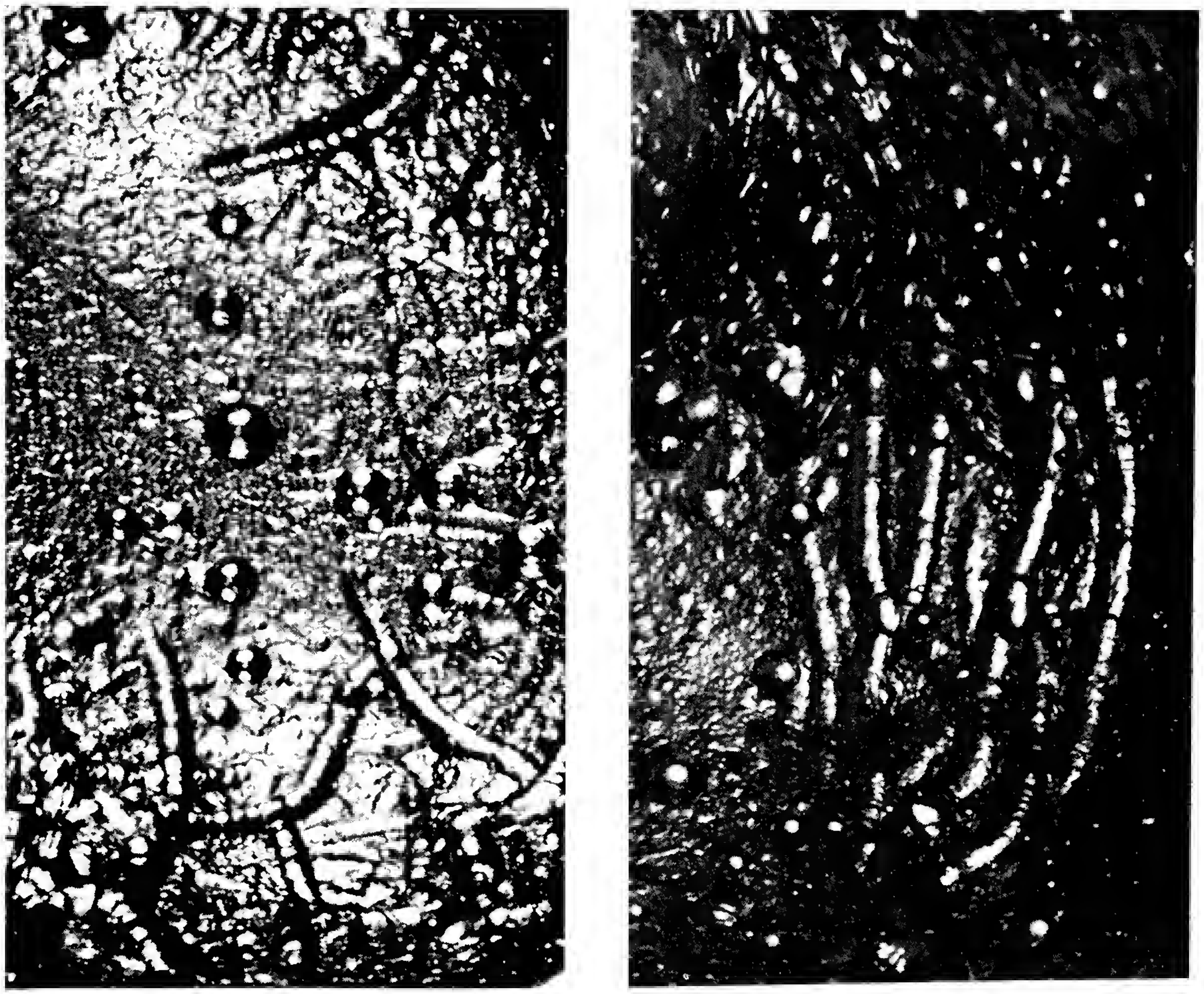
Sculpture of the surfaces

The two surfaces, posterior and anterior respectively, reveal contrasted sculpture patterns. The posterior surface (Fig.1A) is pitted in parts and elsewhere shows smoother, flow-lined patches. The anterior surface (Fig.1B) shows much less pitting and more marked grooving by narrow gutters. These features are fundamentally a result of differential natural solution etching during the several thousand years that the specimen has lain in a soil environment.

The pits range from 0.5 mm to 2.0 mm across and are circular (Fig.3 A&B) to sub-circular and less commonly oval (Fig.2) in outline; many of them are hemispherical. The gutters range from 0.5 mm to 1.5 mm wide, are straight to meandrine in trend (Fig.1 B-F; Fig.2; Fig.3 A&B) and are largely confined to the anterior surface, being more marked in the equatorial regions (Fig.1 B, C&D). These gutters principally trend at right angles to the relatively sharply defined rim separating the posterior and anterior surfaces (Fig.1 C&D; Fig.2), commencing at the rim, traversing the equatorial zone of the anterior surface, and curving and dying out in the less etched regions of the anterior surface (Fig. 1B).

Presumably for much of the time that the specimen has lain embedded in soil, its posterior surface faced downwards, evidently with a slight tilt in view of the more pitted character of one side (top of Fig.1A, and middle of C) relative to the other (bottom of Fig. 1A). In this position of rest, natural etchants carried in soil solutions moving downwards over the

Figure 2.—Sculpture of largest known dumbbell-shaped australite, Cuballing, Western Australia. x3.45 Enlarged end-on aspect of larger gibbosity, showing pits and gutters. Some of the gutters intersect at different levels, some are oblique to the flow line trends of the tektite glass. (Photograph by R. K. Blair).



A B

Figure 3.—Sculpture of largest known dumbbell-shaped australite, Cuballing, Western Australia. x4.7. Enlargement showing randomly developed gutters of different depths, and circular pits, on the anterior surface of the smaller gibbosity (cf. right-hand end of fig. 1, B); note that some of the gutters have a segmented appearance. B.—Enlargement showing sub-parallel gutters some of which inerconnect on the equatorial portion of the anterior surface of the larger gibbosity (cf. lower right-hand end of Fig. 1C); the pitted posterior surface is represented by the upper portion of the photograph. Micro-pits can be observed on the floors and walls of some of the gutters. (Photographs by R. K. Blair).

curved upwardly directed anterior surface acted differentially in equatorial regions to form the gutters.

A feature of the etched-out gutters (and this also applies to some of the pits) is their variability in depth. The gutters shown in Figures 1 and 2 occasionally come into contact with each other at the same level, but sometimes at a different level, some being up to twice as deep as others. The gutters are U-shaped in cross-sectional aspect, so that where shallower gutters meet deeper gutters at an angle the appearance of miniature "hanging valleys" is produced. Such a feature does not seem consistent with an origin by aerodynamic ablational sculpture. Furthermore, the walls and floors of the U-shaped gutters mostly reveal micro-etch pits from place to place. These have resulted (Fig.3B) from local overdeepening, more likely by the process of natural solution etching.

Some of the gutters have a segmented "vermicular" appearance (Fig.3A) where the low walls of adjacent etch pits meet in ridges trending normal to the lengths of the gutters. In other gutters, striae representing part of the sub-surface schlieren pattern of the tektite glass, made evident by differential solution etching, sometimes trend normal to, less frequently almost parallel with, the trends of the gutter walls. These again are not the type of features to be expected from the effects of aerodynamic sculpture, and the striae more likely become evident as a consequence of the etching out by soil solutions of adjacent streaks of glass of slightly different chemical composition.

The walls and floors of several of the pits also reveal the striae and occasionally also possess smaller etch pits, while some pits are twice as deep as other pits of comparable diameter; this evidently partially results from

overdeepening along bundles of schlieren lying approximately normal to the tektite surface. Less etched portions of the anterior surface (Fig.3A) show a pattern like the surface of an orange.

On parts of the posterior surface, the etch pattern follows the trend of the internal schlieren, thus exposing the complex pattern of flow streaks, visible on the bottom half of Figure 1, A, as fine lines.

Solution etch gutters on the posterior surface are fewer, shorter and shallower, compared with the gutters on the anterior surface.

The conclusion is that the sculptural features such as the gutters and many, if not all, of the pits on the anterior and posterior surfaces of the dumbbell-shaped australite from Cuballing, are tertiary features arising from natural, terrestrial, solution-etching, and that they are not due directly to the secondary process of an aerodynamic ablational sculpturing during hypersonic transit through the earth's atmosphere. In substantiation of this conclusion, it is noteworthy that there was no evidence of the formation of gutters on the front surfaces of tektite glass test models during an experimental programme recently conducted by the Space Sciences Laboratory of the General Electric Company, Pennsylvania, U.S.A. This programme was instituted to investigate various criteria suggested for the formation of surface irregularities on tektite bodies, and it was thought there might be a likelihood of the formation of surface grooving by a possible Gortler-type boundary layer instability. Using a relatively narrow range of test environments in the Hypersonic Arc Tunnel (Diaconis and Johnson 1964) no surface grooves resulted.

Features observed under the microscope

A small area of the posterior surface has been chipped, and reveals that a little of the tektite glass has been lost by minute fracture spallation. This evidently occurred subsequently to the discovery of the specimen. The area is towards the right-hand end of Figure 1, A. Examination of this area under a binocular microscope reveals the highly vitreous lustre of the freshly exposed tektite glass and also its conchoidal fracture pattern. The larger of the fracture surface areas, which measures 6 mm by 3 mm in area and is lunate in outline, also reveals secondary ripple fracture.

A thin sliver of the glass was mounted in Lakeside cement for examination of its internal structure under a petrological microscope. The thin sliver resulted from breaking the walls of a pit approximately 0.5 mm across when attempting to free it of relatively firmly lodged adventitious clay constituents. Under crossed nicols of the petrological microscope, the glass revealed almost complete isotropism with no significant strain birefringence. Only very rarely is birefringence weakly shown as a narrow, indefinite, partial zone around one or two of the lechatelierite particles (also isotropic) embedded in the glass. The shapes and sizes of the more readily distinguishable lechatelierite particles are listed in Table 3.

TABLE 3

Shapes and sizes of lechatelierite particles embedded in a small sliver of tektite glass detached from the dumbbell-shaped australite from Cuballing, Western Australia

	Shape	Size (μ)
a	irregular, rod-like	100 x 25
b	sub-spherical	40
c	rod-like	30 x 5
d	roughly triangular	10
e	ellipsoidal with hooked ends	60 x 25

From the Becke line test, it was determined that the lechatelierite particles have a refractive index somewhat below that of the neighbouring isotropic tektite glass, while the glass itself has a much lower index of refraction than that of the mounting medium (Lakeside cement).

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9.—Studies on Western Australian sharks and rays of the families Scyliorhinidae, Urolophidae and Torpedinidae

by R. J. McKay*

Manuscript received 22 June 1965; accepted 21 September 1965

Abstract

Studies on the Families Scyliorhinidae, Urolophidae and Torpedinidae from Australian waters are given with descriptions of two new species in the genus *Urolophus* and one new species in the genus *Narcine*. Four additions to the fish fauna of Western Australia are included. Keys are provided..

Introduction

With the advent of commercial prawn trawling in the Shark Bay and Exmouth Gulf areas, and with the growing popularity of skin-diving and spearfishing in the local waters of the State, the Western Australian Museum has received numerous collections of fishes. Not unexpectedly, many fishes prove to be new records for Western Australia, and a few are new to science.

This paper is based on material in the Western Australian Museum collection. The works of Fowler (1941) and Bigelow & Schroeder (1948, 1953) were basic to this study. Some additional references not given by the above mentioned authors are included.

Family SCYLIORHINIDAE

Rather small, bottom dwelling sharks characterised by possessing an anal fin; two (rarely only one) dorsal fins, the first dorsal fin with at least half of its base posterior to the origin of the pelvic fins. A distinct spiracle present behind eye; eye without nictitating membrane although a nictitating fold below eye is generally present. Mouth with several series of teeth functional, no distinct groove connecting mouth with nostrils; if shallow groove present, no fleshy barbel on anterior margin of nostril. Labial folds more or less developed. Rather attractively marked, inoffensive little sharks found in temperate and tropical latitudes: well represented in Australia. Mostly inhabiting shallow coastal waters.

* Western Australian Museum, Perth, Western Australia.

Key to Genera of Scyliorhinidae found in Australian seas

(1)	Upper edge of caudal fin with a crest of modified, enlarged denticles, outlined below by a narrow band of naked skin	*GALEUS*
	Caudal fin with uniform denticles, no crest or band of naked skin .	2
(2)	No labial folds on jaws. Mouth broadly distensible. Belly capable of distension	*CEPHALOSCYLLIUM*
	Labial folds present on both jaws and around corners of mouth. Mouth and belly not distensible	3
(3)	Nasal flap reaches and slightly overlaps mouth; no hind nasal flap. A well defined fold below eye. Labial folds very long	*ATELOMYCTERUS*
	Nasal flap not reaching mouth; hind nasal valves present. Fold below eye present. Labial folds very short to moderately long .	*HALAELURUS*

Genus *GALEUS* Rafinesque

Galeus Rafinesque 1810 p.13; type species by selection Fowler 1908 p.53. *Galeus metastomus* Rafinesque 1800

Pristiurus Bonaparte 1834; type species *Pristiurus melanostomum* Bonaparte = *Galeus melastomus* Rafinesque 1810.

Figaro Whitley 1928 p.238; type species *Pristiurus (Figaro) boardmani* Whitley 1928.

Diagnosis Two dorsal fins, the first dorsal fin originates over or behind rear part of pelvic fins. Nostrils separated by a broad isthmus and far from mouth. Mouth large and with labial folds around corners. Anal fin longer than second dorsal fin. Denticles along dorsal margin of anterior part of caudal fin enlarged, forming a well defined crest, outlined below by a narrow band of naked skin. One species in Australia.

Galeus boardmani (Whitley)

Pristiurus (Figaro) boardmani Whitley 1928 p.238. Type locality 10 miles NE. Montague Island, southern New South Wales.

Figaro boardmani, Whitley 1929 p. 354; McCulloch 1929-30 p.8; Whitley 1934 p.198; Whitley 1939 p.230, Bass Strait 100-200 fathoms, Great Australian Bight south and west from Eucla 70-450 fathoms; Whitley 1940 pp.90-91, Figs.78 and 83; Whitley 1964 p.33.

Figaro boardmani socius Whitley 1939 p.230; Whitley 1940 pp.90-91; Whitley 1948 p.8; Whitley 1964 p.33.

Galeus boardmani, Fowler 1941 pp.28 and 29; Munro 1956 p.6; Olsen 1958 p.156; Scott 1962 p.24; Stead 1963 p.22.

Differs from all other species in the genus in having the ventral margin of the caudal peduncle, as well as the anterior dorsal margin of the caudal fin, with a conspicuous crest of enlarged denticles.

Known from New South Wales, Victoria, Tasmania, South Australia and southern Western Australia. Specimens recognised by Whitley as a subspecies *G. boardmani socius* from the Great Australian Bight are reported to be lighter in coloration. Not represented in the W.A. Museum.

Genus *CEPHALOSCYLLIUM* Gill

Cephaloscyllium Gill 1862 p.407; type species *Scyllium laticeps* Duméril 1853.

Diagnosis. Head wide and rather flattened, snout short and narrowing sharply forwards. Mouth wide, arched, distensible, and without well developed labial folds. Eye slit-like. Dermal denticles giving body a rough appearance. Belly capable of inflation. One subspecies in Australia.

Cephaloscyllium isabella laticeps (Duméril)

See Fowler (1941 p.3) for references and description. Known from southern New South Wales. Victoria, South Australia and Tasmania. Not yet recorded from Western Australia and not represented in the W.A. Museum.

Genus *ATELOMYCTERUS* Garman

Atelomycterus Garman 1913 p.100; type species *Scyllium marmoratum* Bennett 1830.

Diagnosis. Mouth with long labial folds on upper and lower jaws. Nasal flap with rounded lobes overlapping mouth. Nictitating fold below eye well developed. Second dorsal fin larger than anal fin. Two species in Australia.

Atelomycterus marmoratus (Bennett)

(Fig. 1 a, b, c, d)

Scyllium marmoratum Bennett 1830 p.693; Günther 1870 p.400; Day 1875-78 p.724 pl.190, Fig.2.
Scyliorhinus marmoratus, Regan 1908 p.462.
Atelomycterus marmoratus, Garman 1913 p.100; White 1937 p.108, pls.1b, 3d, etc; Fowler 1941 pp. 62 to 64, Fig.6. (Synonyms and many references).

Coloration variable; young with transverse bands of brown colour separated by light blotches or white spots, becoming irregularly spotted and blotched with age.

Previous records of this species from northern Australia by McCulloch 1910 p.688; McCulloch 1929-30 p.9; Whitley 1932 p.322, Pl.38, Fig.1 a-c, Port Darwin; Whitley 1934a p.198 all refer to *Atelomycterus macleayi*. *A. marmoratus* was not included in the recent list of fishes recorded from Australia (Whitley 1964 p.33).

A male (collected by W. and W. Poole from the Onslow area of Western Australia during September 1964, W.A.M.* P 8629, total length 370 mm.) agrees well with Day's (1875-78 p.724, Pl.190, Fig.2) description and figure and with the description given by Fowler (1941 pp.62-64). A juvenile male, W.A.M. P 8811, total length 99 mm, taken by dip-net in Cygnet Bay, King Sound, Western Australia, by C.S.I.R.O., 15 October 1949, has a striking colour pattern of dark brown cross-bars on a pale background (both specimens figured). Biometrics given in Table 1. New record for Australia.

* Numbers preceded by W.A.M. belong to specimens in registered collection of the Western Australian Museum

TABLE 1

Measurements of Atelomycterus marmoratus *(P8629 and P8811)*, Halaelurus labiosus *(P332 and P11749) and* Halaelurus burgeri *(P8807, P8808 and P8809)*.

Measurement in mm	P8629	P8811	P332	P11749	P8807	P8808	P8809
Total length	370	99	487	585	285	320	285
Labial furrow Upper	12	3.0	15	20	0.5	0.5	0.5
Labial furrow Lower	13	3.7	17.5	21	3	4.2	4
Snout to : outer nostrils	11	2.5	9	11	7	8.5	8.5
: eye	25	6.5	22	24	15	16	15
: spiracle	37	9.4	35	45	25	25	25
: mouth	20	4.8	13	18	13	14	14
: 1st gill opening	59	16.4	60	75	35	40	38
: 3rd gill opening	69	19.2	73	92	41	46	45
: 5th gill opening	77	21.0	84	107	47	52	51
: pectoral origin	72	19.3	80	101	43	50	49
: 1st dorsal origin	178	45.9	239	290	113	129	116
: 2nd dorsal origin	256	64.2	325	396	178	201	180
: anal fin origin	244	60.3	305	371	160	184	160
: lower caudal origin	306	75.5	380	461	217	246	215
: pelvic insertion	163	40.0	206	252	100	114	103
Distance between exposed nostrils	20	6.3	23	27	5	5	5
Mouth width	26	7.3	31	37	20	22	20
Eye horizontal diameter	11	2.7	12	14	9	9.3	10
Interorbital (mid.)	25	9.0	26	33	18	19	19
First dorsal fin : base	29	6.0	34	44	20	19	17
: last ray	10	2.6	12	16	6.5	7.3	7
: height	20	5.9	25		13	14	13
Second dorsal fin : base	30	7.2	36	43	20	21	19
: last ray	9	3.0	11	16	6	6.3	6
: height	19	5.5	24	35	11	11	12
Anal fin : base	24	8.0	45	55	24	24	20
: last ray	7	2.8	9	12.5	6	7	6
: height	11	3.5	14	22	10	10	9
Pectoral fin : base	18	4.0	21	26	15	16	14
: anterior margin	38	12.0	49	70	29	31	29
Pelvic fin : base	20	4.5	29	32	10	12	12
: anterior margin	27	7.0	35	45	17	18	18
Trunk at pectoral origin : height	30	8.1	41	45	25	24	24
: width	36	8.8	49	58	31	37	33

Atelomycterus macleayi Whitley

Scyliorhinus marmoratus (*non* Bennett), McCulloch 1910 p.688.

Atelomycterus marmoratus (*non* Bennett), McCulloch 1929-30 p.9, north Australia; Whitley 1932 p.322, pl.38, Fig.1a-*c*, Port Darwin; Whitley 1934a p.198, reference only.

Atelomycterus macleayi Whitley 1939 p.230, type locality Port Darwin, Northern Territory; Whitley 1940 pp.92-93, Figs.78, 86 and 87, Darwin and Melville Island; Whitley 1947 p. 148. egg case from Turtle Island; Whitley 1948 p.8, area 5, Western Australia; Munro 1956 p.6; Whitley 1964 p.33; Taylor 1964 p.54.

Very similar to *A. marmoratus* but has coloration "Brownish with darker spots and markings arranged in band-like groups along the back" (Whitley 1940 p.93) and differs in having the egg case without tendrils on anterior end. The egg case of this species has been recorded from Western Australia by Whitley (1947 p. 148) but adults have not been discovered. Not represented in the W.A. Museum.

Genus *HALAELURUS* Gill

Halaelurus Gill 1862 p.407; type species *Scyllium burgeri* Müller and Henle 1841.

Aulohalaelurus Fowler 1934 p.237; type species *Catulus labiosus* Waite 1905.

Asymbolus Whitley 1939 p.229; type species *Scyllium anale* Ogilby 1885.

Juncrus Whitley 1939 p.229; type species *Scyllium vincenti* Zietz 1908.

Diagnosis. Snout short. Mouth large, with labial folds extending around each corner. Nostrils with valves not reaching mouth; no groove between nostrils and mouth. First dorsal fin behind origin of ventral fin.

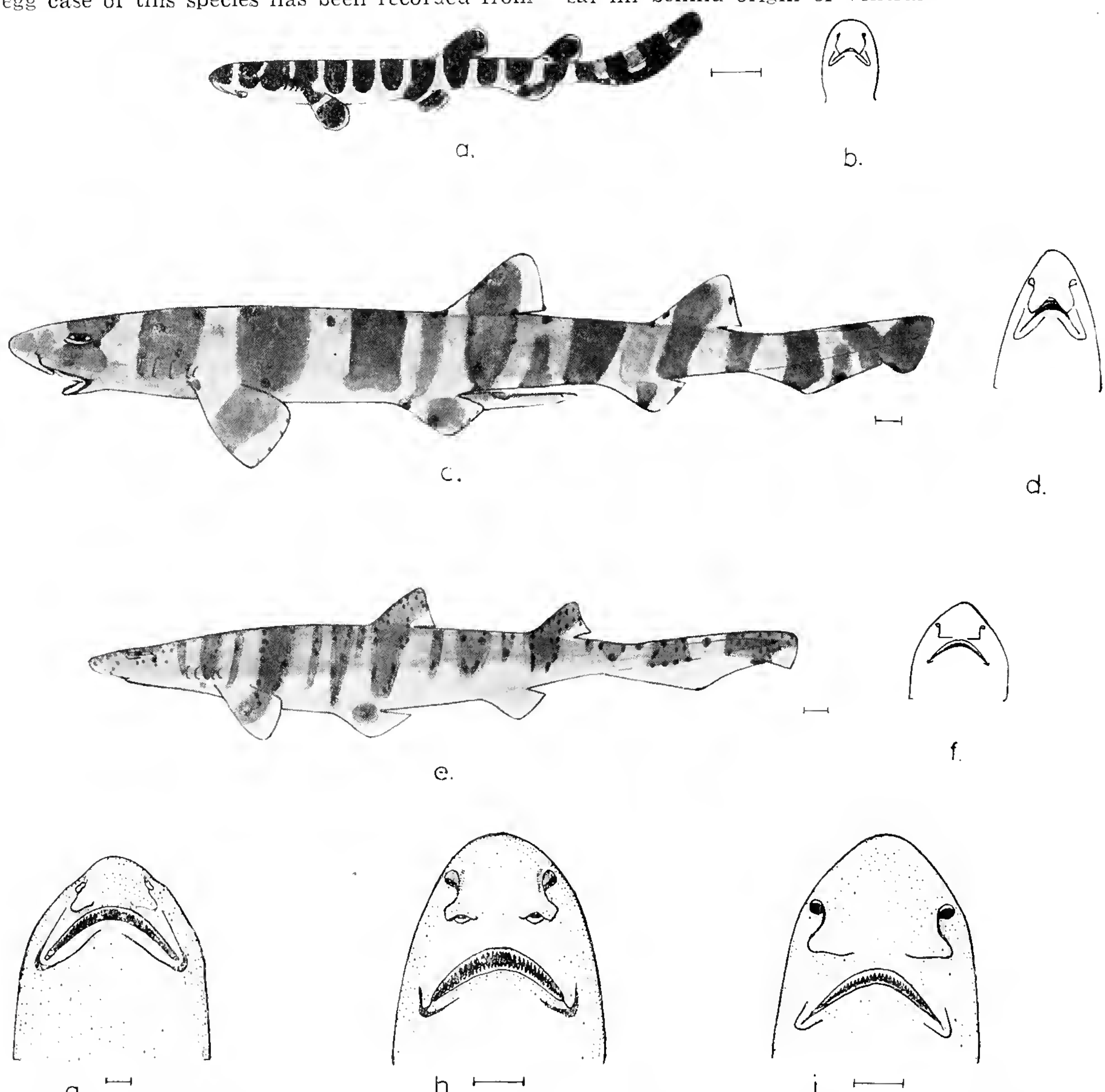


Figure 1.—Western Australian catsharks. a, b: *Atelomycterus marmoratus* juvenile male, P 8811, total length 99 mm. a. lateral view, b. ventral surface of head; *c*, d: *Atelomycterus marmoratus* male, P 8629, total length 370 mm. c. lateral view, d. ventral surface of head; e, f: *Halaelurus bugeri* female, P 8807, total length 285 mm. e. lateral view, f. ventral surface of head; g: *Halaelurus labiosus*, ventral surface of head; h: *Halaelurus analis*, ventral surface of head; i: *Halaelurus vincenti*, ventral surface of head.

Key to species of Halaelurus in Australian seas

(1)	Labial folds greatly developed on upper and lower jaws	*labiosus*
	Labial folds moderate, lower fold not extending halfway to symphysis of lower jaw	2
(2)	Upper labial folds very short and rather inconspicuous	*burgeri*
	Upper labial folds well developed	3
(3)	Body light with scattered dark brown spots on body and fins	*analis*
	Body dark with ill-defined darker cross-bars and blotches; hinder part of head, body and fins, with creamy white spots	*vincenti*

Halaelurus labiosus (Waite)

(Fig. 1g)

Catulus labiosus Waite 1905 p.57, Fig.23, type locality Fremantle, Western Australia.
Halaelurus labiosus, Garman 1913 p.88; Ogilby 1916 pp.77-78; Fowler 1941 p.51; Munro 1966 p.6; Stead 1963 p.23; Taylor 1964 p.54.
Scyliorhinus labiosus, McCulloch 1929-30 p.8.
Aulohalaelurus labiosus, Whitley 1934b p.153, Fig.1; Whitley 1940 p.89, Figs.78 and 80; Whitley 1948 p.8; Whitley 1964 p.33.

Nasal valves not overlapping mouth. Labial folds extending nearly to symphysis of lower jaw. Colour dark above, paler below. Head, body and fins with scattered large black spots. Body with some scattered small white spots on sides. Type in Western Australian Museum. Distribution. Appears to be restricted to Western Australia, actual records are: W.A.M. P 332, male 487 mm, t.l., Cottesloe; P 1955, male 542 mm t.l., Fremantle; P 4151, male 480 mm t.l., Rottnest Island; P 5690, female 673 mm t.l., Cottesloe; P 5919, female 645 mm t.l., Yallingup; P 5920, female 514 mm t.l., Point Peron, Fremantle area; P 7070, female 461 mm t.l., Albany; P 8657, male 626 mm t.l., Albany; P 11749, male 585mm t.l., Rat Island anchorage, Abrolhos Islands. Not recorded east of Albany or north of Abrolhos Islands. Records of this species from Queensland, Northern Territory and northern Western Australia are evidently erroneous as Whitley (1940 p. 89) suggests. I also agree with Taylor (1964 p. 54) that these records are probably referable to *Atelomycterus macleayi* (or *A. marmoratus*). Stead (1963 p. 23) is in error in stating that *H. labiosus* "appears to be fairly widespread around the northern parts of Australia . . . ." Biometrics of specimens P 332 and P 11749 given in Table 1.

Halaelurus burgeri (Müller and Henle)

(Fig. 1 e,f)

Scyllium burgeri Müller and Henle 1841 p.8, pl.2; Günther 1870 p.404.
Scyliorhinus buergeri, Regan 1908 p.461.
Halaelurus burgeri, White 1937 p.107, pls 2e, 3a; Fowler 1941 pp.44-45.

Upper labial folds very short. Nine or ten brown cross-bars outlined with small blackish spots, alternating with narrow cross-bars or lines of dark spots, on a light brown background. Head, dorsal fins, pectoral, and ventral fins, with small dark spots.

This new record for Australia is based on three examples all trawled in 21-29 fathoms, Shark Bay, Western Australia, collected by Mr. E. Barker on F.R.V. "Peron": a male, W.A.M. P 8809, total length 285 mm, 21 September, 1964; a male, W.A.M. P 8808, total length 320 mm, 14 November, 1964; a female, W.A.M. P 8807, total length 285 mm, 15 November, 1964. Biometrics given in Table 1.

Distribution. India, East Indies, Philippines, China, Formosa, Japan (Fowler 1941) and now Western Australia.

Halaelurus analis (Ogilby)

(Fig. 1 h)

Scyllium anale Ogilby 1885 pp.445 and 464; type locality Middle Harbour, Port Jackson; Regan 1908 p.460.
Catulus analis, Waite 1899 p.31, pl.2, Fig.1, New South Wales; Waite 1906 p.228, pl.40, Fig.38, egg cases.
Scyliorhinus analis, McCulloch 1911 p.3, Bass Strait and New South Wales, 14-45 fathoms; McCulloch 1929-30 p.8.
Halaelurus analis, Garman 1913 p.85; Waite 1921 p.18, Fig. 21; Waite 1923 p.36; Fowler 1941 p.48, New South Wales, Victoria, Tasmania, South Australia; Munro 1956 p.6; Olsen 1958 p.156; Scott 1962 p.25; Stead 1964 pp.22-23.
Asymbolis analis, Whitley 1940 p.89; Whitley 1948 p.8; Whitley 1964 p.33.

Nasal lobes not reaching mouth, their width about equal to interspace. Brownish above with about 8 diffuse slightly darker blotches on back; head, body, and fins with scattered brown spots.

Distribution. Southern New South Wales, Victoria, Tasmania, South Australia and southern Western Australia. (W.A.M. P711, Bald Island, east of Albany).

Halaelurus vincenti (Zeitz)

(Fig. 1 i)

Scyllium vincenti Zeitz 1908 p.287, type locality Kangaroo Island, South Australia.
Scyliorhinus vincenti, McCulloch 1911 p.4, pl.2, Figs.1 and 3; McCulloch 1929-30 p.8, Investigator Strait and Kangaroo Island, South Australia.
Scylliorhinus vincenti, Waite 1921 p.17.
Halaelurus vincenti, Waite 1923 p.35; Fowler 1941 p.50; Munro 1956 p.6; Olsen 1958 p.156; Scott 1962 p.25; Stead 1963 p.23.
Juncrus vincenti, Whitley 1940 p.90; Whitley 1948 p.8; Whitley 1964 p.33.

Brown above with ill-defined cross-bars, some dark blotches on sides. Head, body, tail and fins with many white spots.

Distribution. Victoria, South Australia, southern Western Australia (W.A.M. P3777, Esperance), and Tasmania.

Family UROLOPHIDAE

Snout little produced. Tail short, with a well developed caudal fin. One or occasionally two stout serrated spines on tail. Small rays not exceeding three feet in length. One genus in Australia, represented by ten species.

Genus *UROLOPHUS* Müller and Henle

Urolophus Müller and Henle 1837 p.17; type species *Raja cruciata* Lacepede 1804.

Diagnosis. Small rays having a well developed caudal fin preceded by a strong saw-edged spine (or spines). Tail shorter than body in some species. A small dorsal fin may be present.

Key to species of Urolophus in Australian seas

(1)	Tail short. Tail length less than than distance between mouth and centre of cloaca	2
	Tail long. Tail length greater than distance between mouth and centre of cloaca	4

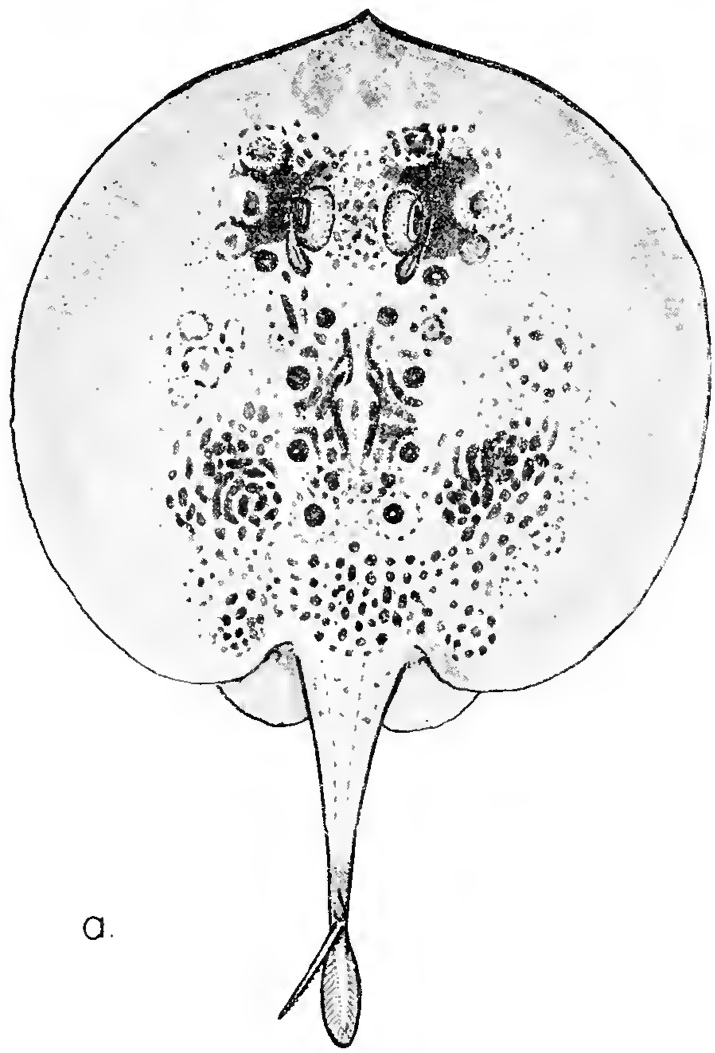
(2)	Disc spotted; length of eye half spiracle length	*gigas*
	Disc not spotted, back uniform or with longitudinal stripe and sometimes transverse markings; length of eye greater than half spiracle length	3
(3)	Back with dark longitudinal stripe and dark transverse markings	*cruciatus*
	Back with indefinite brown longitudinal stripe or back uniform yellowish. No transverse markings	*sufflavus*
(4)	Internasal flap with a broad fringe on its posterior margin. Nostrils with broad lobes posteriorly. Tail without lateral folds	5
	Internasal flap with a narrow fringe or with lobules on its posterior margin. Nostrils without broad posterior lobes. Tail with lateral fold or keel on each side	6
(5)	Angular margin of spiracle projecting	*testaceus*
	Angular margin of spiracle not projecting	*mucosus*
(6)	Papillae behind lower jaw numerous and close together . .	8
	Papillae behind lower jaw few and sparse	7
(7)	Disc slightly broader than long. Back uniform light green, sometimes with a broad blackish bar across interorbital space and extending outward on either side eye	*viridis*
	Disc much broader than long. Back not green	9
(8)	Eye about 2 in interorbital space. Outline of disc somewhat rhomboidal. Disc sandy brown above, speckled with closely set white dots	*bucculentus*
	Eye about equal to interorbital space. Outline of disc almost circular. Disc sandy brown above, spotted with black dots and blotches with 12 or more conspicuous blue centred, large brown spots	*circularis*
(9)	Outer margin of nostril with a conspicuous tentacle; anterior of nasal flap with well developed lobes laterally. Back uniform light brown	*lobatus*
	Outer margin of nostril without a conspicuous tentacle; anterior of nasal flap without lateral lobes. Back grey, with two faint Plumbeous cross bars on hinder part of head	*expansus*

Urolophus circularis species nova
(Fig. 2, a, b)

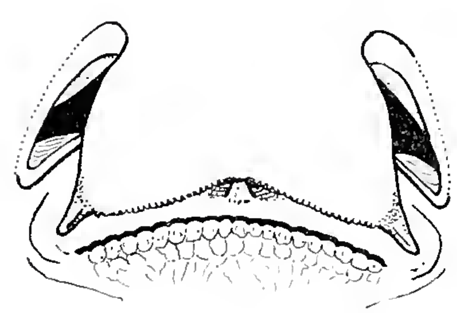
Material. Holotype: Female, total length 478 mm, Western Australian Museum reg. No. P 8191, collected by E. A. Robinson and R. J. McKay, in 5 fathoms near Seaward Reef, 3 miles west of Carnac Island, Fremantle area, Western Australia, 10 December, 1961.

Description. Disc slightly broader than long; somewhat broadly circular in general outline, anterior margin broadly rounded with a small projecting snout; margins of disc in preorbital region with recurved radials forming a rounded, thickened edge; lateral margins rounded, posterior corner moderately rounded, inner margins weakly concave. Tail, from centre of cloaca, longer than the distance between mouth and centre of cloaca. Tail tapering gently, moderately flattened dorso-ventrally, rounded slightly beneath; a well developed dorsal fin present, followed immediately by a stout spine bearing 35-44 sharp recurved lateral teeth. Caudal fin rounded at tip, with weakly convex upper and lower margins, depth of caudal fin about equal to length of dorsal fin base. Tail bearing a well developed dermal ridge laterally.

Snout in front of orbits about 3.5 times in distance between snout tip and centre of cloaca. Snout tip to mouth about 3.7 in snout to cloaca centre. Orbit about as long as interorbital space. Spiracles with outer margin extending to about anterior third of orbit, the interior



a.



b.

Figure 2.—Stingaree. *Urolophus circularis* sp. nov, *Holotype* P 8191, total length 478 mm. a: dorsal view; b: mouth and nasal curtain.

opening extending to about posterior third of orbit. Spiracles can be completely closed by a cutaneous curtain or flap present on the upper spiracular margin below eye. Distance between spiracles about twice horizontal diameter of orbit.

Nasal curtain thickened laterally, corner produced forming lobes; hind margin of curtain weakly fringed. Nostrils transverse, anterior margins with a thin cutaneous flap which covers half of exposed nostril; hinder margin with outer half expanded into a fleshy lobe that projects inwards. Lateral margins of nostril thickened but not produced into broad lobes.

Mouth slightly arched, lower jaw with numerous closely set papillae. Teeth pavement-like, close together, in about 24 diagonal rows in upper jaw and in 26 rows in lower jaw; both jaws with about 15 series of teeth in the mid-line, only 6 series in upper jaw and about 7 series in the lower jaw are functional. Immediately behind both bands of teeth, inside mouth, are transverse curtains; the curtain on the roof of the mouth is distinctly fringed, and is followed by a less well-developed, non-fringed, curtain; the curtain on the floor of the mouth is less fringed than the curtain on roof of mouth, and is followed by a transverse row of 10 simple, slender papillae.

Gill-openings widely separated anteriorly, the distance between the last gill-openings about 1.5 in distance between first gill-openings.

Skin on disc and tail naked above and below. Minute pores on disc, more numerous in pre-orbital area and towards lateral margins Some minute pores on dorsal surface

Pelvic fins broadly rounded, their posterior margin gently recurved to merge with the tail.

Colour. Dorsal surface of disc a light sandy grey, with a mauve tinge throughout, covered with spots and blotches of dark brown. Some spots, especially in the mid-line, merged together; suborbital regions with extensive brown mottling and isolated diffuse brown spots enclosing a dark edged light blue centre; each brown spot surrounded by a light area. Light mauve-grey below. Tail light dusky brown above and below, a slightly darker area surrounds dorsal fin.

Dimensions expressed as per cent. of total length. Snout tip to tip of caudal fin (total length) 478 mm. Disc: extreme breadth 60.9.

Disc:	length (not including pelvics 59.0
	length to inner pectoral margin 53.4
Snout tip to:	orbits 15.7
	mouth 15.1
	Cloaca centre 55.4
	dorsal fin origin 75.1.
Orbits:	horizontal diameter 5.2
	distance between 5.7
Spiracle:	length 5.2
	distance between 10.7
Mouth:	breadth 7.7
Nostrils:	distance between exposed inner margins 6.1
Nasal flap:	posterior breadth 9.4
Gill openings:	length of 1st 2.1
	3rd 2.3
	5th 1.3
Dorsal fin:	vertical height 1.9
	length of base 4.0
Tail spine:	length from base 13.6
Caudal fin:	length from ventral origin 16.7
	depth 4.2
Tail keel:	length 10.9

Urolophus gigas Scott

Urolophus gigas Scott 1954 p. 105; Munro 1956 p.19; Scott 1962 p.44; Whitley 1964 p.34.

Distribution. Only known from South Australia (St. Vincent and Spencer Gulfs).

Urolophus cruciatus (Lacépède)

Raja cruciata Lacépède 1804 pp.201, 210.
Urolophus cruciatus, Günther 1870 p.485, Port Arthur; Macleay 1881 p.314; Waite 1899 p.43; McCulloch 1911 p.14; Waite and McCulloch 1915 p.460, Great Australian Bight; McCulloch 1916 p.171; Waite 1921 p.32 Fig.45; McCulloch 1929-30 p.27; Whitley 1940 p.216 Fig.246; Fowler 1941 p.442; Whitley 1948 p.10; Munro 1956 p.18; Scott 1962 p.43; Stead 1963 p.172; Whitley 1964 p.34.
Urolophus ephippiatus Richardson 1846 p.35, pl.24.

Not represented in the Western Australian Museum.

Distribution. Victoria, Tasmania, South Australia and southern Western Australia.

Urolophus sufflavus Whitley

Urolophus cruciatus (non Lacépède), Waite 1899 p.43; Waite 1904 p.10.
Urolophus aurantiacus (non Müller and Henle) McCulloch 1916 p.172, pl.49; McCulloch 1927 p.12 pl.3, Fig.39a; Stead 1963 pp.170-172.
Urolophus sufflavus Whitley 1929, based on McCulloch 1916; McCulloch 1929-30 p.27; Whitley 1940 p.215, Fig. 244; Fowler 1941 pp.441-442; Munro 1956 p.18; Whitley 1964 p.34.

Fowler (1941 p.442) remarks . . . "Apparently differs from the Japanese *Urolophus aurantiacus* in the dark median dorsal stripe."

Distribution. Only known from southern New South Wales. Not represented in the Western Australian Museum.

Urolophus testaceus (Müller and Henle)

Trygonoptera testacea Müller and Henle 1841 p.174; Waite 1899 p.44; Garman 1913 p.410.
Trygon testacea, Zeitz 1908 p.292.
Urolophus testaceus, Günther 1870 p.486, Sydney, Cape Upstart, Australia; Macleay 1881 p.315; Waite 1899 p.44; McCulloch 1916 p.174, pl.50; Ogilby 1916 p.86; Jumpin Pin, Cape Moreton, South Hill, Low Bluff, Double Island Point; Waite 1921 p.32, Fig.46; McCulloch 1929-30 p.27, Queensland, New South Wales, Victoria, South Australia; Whitley 1940 p.213, Figs.191, 226 and 248; Fowler 1941 p.447; Munro 1956 p.18; Scott 1962 p.42; Stead 1963 p.175; Marshall 1964 p.41; Whitley 1964 p.34.

First record for Western Australia based on 7 examples: W.A.M. P 3743, Fremantle, trawled 3 September 1954, total length 305 mm; W.A.M. P 7691, King George Sound, Albany, trawled by L.F.B. "Bluefin", 1959, total length 207 mm; W.A.M. P 8192-8195, Cottesloe Bank, trawled by F.R.V. "Peron", 17 April 1960, total lengths 407 mm, 360 mm, 328 mm, 180 mm; W.A.M. P 8206, Garden Island, January 1960, total length 434 mm

Distribution. Southern Queensland, New South Wales, Victoria, South Australia and now Western Australia.

Urolophus mucosus Whitley

Urolophus (Trygonoptera) mucosus Whitley 1939 p.257, type locality King George Sound, Western Australia; Whitley 1940 p.219, Fig.249; Whitley 1948 p.10; Munro 1956 p.19; Whitley 1964 p.34.

Closely allied to *U. testaceus* but the snout is rounded and the inner margin of the spiracle lacks a projecting tip. Two specimens in the Western Australian Museum agree well with Whitley's description and figure. W.A.M.

P 4207, Perth Waters (off Fremantle) 26 January 1958, total length 464 mm; W.A.M. P 8196, Cottesloe Bank, trawled by F.R.V. "Peron", 17 April 1960, total length 284 mm. The Western Australian Museum has a number of specimens that show much variation in body proportions and coloration, and a large series may prove *U. mucosus* to be within the limits of a very variable *U. testaceus.* Although all authors have described *U. testaceus* as having the disc uniformly coloured above, I have specimens (that I refer to this species for want of comparative material) with dark brown areas around the eyes and spiracles, and on the disc. The shape of the disc of the uniformly coloured examples differs somewhat from all specimens possessing dark markings. A comparison between specimens from New South Wales and a large series of Western Australian material is clearly needed. Previously known from southern Western Australia, *U. mucosus* is now recorded from the west coast.

Urolophus viridis McCulloch

Urolophus viridis McCulloch 1916 p. 176, Babel Island, Bass Strait; Green Cape, Newcastle, Jervis Bay, Botany Bay, Port Jackson, Sandon Bluffs, New South Wales; Tasmania. McCulloch 1929-30 p.28; Whitley 1940 pp.219-220, Fig.250; Fowler 1941 p.445; Munro 1956 p.18; Stead 1963 p.174; Whitley 1964 p.34.

First record for Western Australia based on 7 males and 5 females, W.A.M. P 14108 to P 14119, 145 mm t.l. to 300 mm t.l., trawled in 17 to 18 fathoms, north-east of Rottnest Island, Western Australia, by L.F.B. "Bluefin", September 18, 1965, collected by the author and Mr. C. Disley. This species could be easily distinguished from all other rays in the trawl catch, as the dorsal surface of the disc was a light moss-green in fresh specimens.

Distribution. New South Wales, Victoria, Tasmania, and now Western Australia.

Urolophus lobatus species nova

Material. Holotype: Female, total length 205 mm, Western Australian Museum regd. No. P 14133, collected in 18 fathoms north-east of Rottnest Island, Western Australia, 18 September 1965. Paratypes: 12 males and 6 females trawled in 17-18 fathoms, north-east of Rottnest Island, Western Australia, collected by the author on board L.B.F. "Bluefin," 18 September 1965. W.A.M. P 14120, 206 mm t.l.; P 14121, 201 mm t.l.; P 14122, 260 mm t.l.; P 14123, 225 mm t.l.; P 14124, 251 mm t.l.; P 14125, 188 mm t.l.; P. 14126, 260 mm t.l.; P 14127, 202 mm t.l. ; P 14129, 204 mm t.l.; P 14130, 250 mm t.l.; P 14131, 212 mm t.l.; P 14134, 223 mm t.l.; P 14135, 208 mm t.l.; P 14136, 197 mm t.l.; P 14137, 288 mm t.l.; P 14138, 239 mm t.l.; P 14140, 198 mm t.l.

Description. Disc much broader than long, greatest breadth 64.9% (paratypes 59.9% to 68.6%) in total length. Greatest length of disc 53.7% (51.4% to 56.9%) in total length.

Tail, from the centre of the cloaca, longer than distance between the mouth and the centre of the cloaca. The tail tapers gently, rather flattened above and below, and bears a well developed dermal ridge laterally. Caudal fin long and narrow, with a slightly pointed tip (some paratypes have a rounded tip to the caudal fin). Tail 50.2% (tail becomes proportionately shorter with an increase in total length, from 53.3% of total length at 210 mm t.l., to 46.6% at 260 mm t.l.) of total length.

Snout with a very short pointed tip, its length in front of the orbits 24.5% (24.0% to 27.3%) in distance between tip of snout and centre of cloaca. Tip of snout to posterior margin of nasal flap 27.0% (24.8% to 28.0%) in distance between tip of snout and centre of cloaca.

Orbits of eyes about equal to interorbital space, and 44.8% (36.8% to 45.8%) in distance before orbits.

Spiracles small, their outer margin extends to below the anterior third of the orbit, and their posterior rim extends to less than half the orbital length behind the eye.

Nasal curtain with well developed lobe like expansions on the anterior lateral margins. The lobes are slightly concave on outer surface, convex on inner surface, and completely close the nostrils when pressed flat. The outer margin of the nasal opening has a short (but conspicuous) tentacle on the post-lateral extremity, and a flat, rounded lobe, almost covering the nostril, internally. The posterior margin of the nasal flap, or curtain, is very weakly fimbriate.

Mouth transverse, its width is a little less than the greatest width of the nasal curtain. Very few papillae behind lower jaw. Teeth pavement like, bearing a low transverse ridge; about 20 rows of teeth in the upper jaw, and about 21 rows in the lower jaw. Behind the teeth in the upper jaw is a fringed, transverse, fleshy curtain, and behind the teeth in the lower jaw are 9 to 10 raised papillae.

Pelvic fins broadly rounded at all angles; the origin of the pelvic fins is situated before the vent, and the distance between the pelvic fin origin and the tip of the snout is 46.3% (45.6% to 48.5%) of the total length. Colour. Uniform pale brown above, pale grey to white below. Tip of the caudal fin darker than remainder of fin. The dorsal spine is a bright lemon-yellow. No markings on disc.

Dimensions of the holotype in millimetres:

Snout tip to the tip of the caudal fin (total length) 205 mm.

Disc:	extreme breadth 133.
	length (not including pelvics) 110.
	length to inner pectoral margin 101.
Snout tip to:	orbits of eyes 25.
	mouth 28.
	Origin of pelvic fins 95.
	centre of cloaca 102.
	origin of caudal spine 149.
Orbits:	horizontal diameter 11.
	distance between 10.
Spiracle:	length 11.
	distance between 18.
Mouth:	breadth 11.
Nasal flap:	anterior least width 7.
	posterior maximum width 13.
	length 6.
Pelvic fin:	base 21.
	distance between origins 31.
Caudal fin:	length from ventral origin 49.
	depth 8.
Tail keel:	length 57.

The lobate nasal curtain and the form of the nostrils clearly distinguish this species from all other previously described urolophids. The only species with a wide disc other than *Urolophus*

expansus is *Urolophus kaianus* Günther (original description copied in part by Fowler (1941 p. 445). The description given by Günther 1870 is inadequate and no illustration is supplied.

Mr. P. J. Whitehead, of the British Museum of Natural History, kindly forwarded an excellent drawing of the nostrils and nasal flap of the largest of the two syntypes of *U. kaianus* (235 mm in total length); this drawing shows the nasal flap to be relatively simple, without lobate anterior lateral margins, and the outer margin of the nostril lacks the tentacle found on all specimens of *U. lobatus*.

Urolophus expansus McCulloch

Urolophus expansus McCulloch 1916 p.178, Fig.2, type locality Great Australian Bight in 80-120 fathoms; Waite 1921 p.33, Fig. 47; McCulloch 1929-30 p.27; Whitley 1940 p.218, Fig.247; Fowler 1941 p.446; Munro 1956 p.18; Scott 1961 p.43, Great Australian Bight South Australia; Whitley 1964 p.34.

Distribution. Trawled in 80-120 fathoms in the Great Australian Bight, South Australia, not yet recorded from Western Australia.

Urolophus bucculentus Macleay

Urolophus bucculentes Macleay 1884 p.172, type locality outside Port Jackson in 40-60 fathoms; McCulloch 1916 p.177, Bass Strait, in 70-100 fathoms; McCulloch 1921 p.466, pl.41, Figs.1-3; McCulloch 1929-30 p.27, New South Wales, Tasmania; Whitley 1940 p.216, Fig.245; Fowler 1941 pp.443-444; Munro 1956 p.18, southern New South Wales, Victoria, and Tasmania; Stead 1963 p.173; Whitley 1964 p.34.

Trygonoptera bucculenta Waite 1899 p.44, pl.5, text Fig.3, Garman 1913 p.410.

Distribution. Southern New South Wales, Victoria and Tasmania. Not recorded from Western Australia, although Stead (1963 p. 173) suggests that this species may be present in Western Australian waters.

Family **TORPEDINIDAE**

Sluggish fishes, remaining on the bottom partially buried in sand, these rays are well known for their capability of delivering a powerful electric shock if handled or trodden upon by an unwary swimmer. The electric organs consist of large numbers of vertical columnar structures arranged more or less regularly in a honeycomb fashion on each side of the disc. The columns are divided by transverse electric discs or plates of jelly-like consistency. The whole organ occupies the entire thickness of the disc, and may often be discerned through the thin overlying skin on the ventral surface.

Outline of the disc is almost circular in some species, rather elongate in others; skin naked above and below. Tail short, sometimes rudimentary, bearing two dorsal fins and a well developed caudal fin. No spines on tail.

Eyes developed and functional in some species, almost obsolete in others. Spiracles close behind eyes, with or without fringes or papillae.

Three genera in Australia.

Key to genera of Torpedinidae found in Australian seas

(1)	Tail shorter than disc	2
	Tail longer than disc	*NARCINE*
(2)	Pelvic fins united into a smaller disc. Teeth with two or three cusps	*HYPNOS*
	Pelvic fins not united. Teeth with only one cusp	*TORPEDO*

Genus *HYPNOS* Duméril

Hypnos Duméril 1852 p.277; type species *Hypnos subnigrum* Duméril 1852 = *Lophius monopterygius* Shaw and Nodder 1795.

Hypnarce Waite 1902 p.180; type species *Hypnos subnigrum* Duméril 1852.

Diagnosis. Disc broader than long, flattened. Tail short and rudimentary, bearing two small dorsal fins situated close together. Mouth not protractile. Teeth numerous and with three cusps. Spiracle close behind eye, with margin of spiracle fringed. Eyes small, about half diameter of spiracle. Pelvic fins united into a smaller disc.

One species, endemic to Australia.

Hypnos monopterygium (Shaw and Nodder)

Lophius monopterygius Shaw and Nodder 1795 pls.202 and 203.

Hypnos subnigrum Duméril 1852 p.279; Günther 1870 p.453, West Australia; Macleay 1880 p.310, Port Jackson and West Australia; Haswell 1884 p.104, pl.11, Figs.6-9; Howes 1890 p.669, pl.57; Waite 1899 p.42; Zeitz 1908 p.292; McCulloch 1921 pl.38, Figs.3-4; Fowler 1941 p.340.

Hyprarce Subnigrum, Garman 1913 p.304; McCulloch 1921 p.467, New South Wales; Great Australian Bight; Port Jackson and Clarence River estuary; Rottnest Island, Western Australia; Waite 1921 p.28, Fig.41.

Hypnarce subnigra, Waite 1902 p.180; McCulloch 1929-30 p.25; Marshall 1964 p.34, pl.13.

Hypnarce monopterygium, Whitley 1940 p.165, Figs.11, 187, and 188; Whitley 1948 p.9.

Hypnos monopterygium, Munro 1956 p.20; Scott 1962 pp.50-51; Stead 1963 pp.146-148, Fig.47; Whitley 1964 p.34.

This strangely shaped electric ray is not uncommon in Western Australian waters, and has been taken on the southern and lower western coastline northwards to Shark Bay where it is frequently trawled.

Material examined in Western Australian Museum: 4 males, total length 240mm-400mm, 9 females, total length 192mm-548mm from: Emu Point (Albany), Flinders Bay (near Augusta), Yallingup, Bunker Bay (near Cape Naturaliste), Safety Bay, Naval Base, Woodmans Point, Rottnest Island, Fremantle, Lancelin Island, Beagle Island, and Shark Bay. I have recorded specimens from Cottesloe, City Beach, Wallabi Islands (Houtman Abrolhos), Shark Bay (many localities within Shark Bay in 7-11 fathoms, smallest example was a male of 155 mm, largest specimen a female of 510 mm total length).

Distribution. Southern Queensland, New South Wales, South Australia and Western Australia.

Genus *TORPEDO* Houttuyn

Torpedo Houttuyn 1764 p.453; type species *Raja torpedo* Linnaeus 1758.

For generic synonyms see Bigelow and Schroeder (1953 p.90).

One species in Australia.

Torpedo macneilli (Whitley)

Torpedo fairchildi (*non* Hutton), McCulloch 1919 pp.171-172, pl.25, 49 fathoms off Green Cape, New South Wales (description); Stead 1963 pp.145, 148 and 149.

Narcobatus fairchildi (*non* Hutton), Waite 1921 p.28, Fig. 40, South Australia; McCulloch 1926 p.159, Bass Strait; Great Australian Bight, south of Eucla on the border between South and Western Australia, 80-320 fathoms; McCulloch 1927 p.10, pl.3, Fig.32a.

Notastrape macneilli Whitley 1932 p.327; Whitley 1940 p.162, Fig.181; Fowler 1941 pp.345-346 (as synonym of *T. fairchildi* Hutton); Whitley 1948 p.9, area 1, Western Australia; Whitley 1964 p.34.

Torpedo macneilli, Bigelow & Schroeder 1953 pp.93, 95; Munro 1956 p.20; Scott p.51.

Doubtfully distinct from *Torpedo fairchildi* Hutton, found in New Zealand. Whitley (1940 p.162) states . . . "It may be only a subspecies of the New Zealand *fairchildi*". Fowler (1941 p.345) unites *T. macneilli* with *T. fairchildi*, but Bigelow & Schroeder (1953), while doubting the validity of *T. macneilli* (p 90) state (footnote No. 63, p.95) . . . "the rear end of the base of its (*T. macneilli*) first dorsal is considerably posterior to the rear ends of the pelvic fin bases, not in a line with the latter, as appears to be the case in the New Zealand *T. fairchildi* . . . ." Bigelow & Schroeder retain *T. macneilli* as a separate species in their key to species of the genus *Torpedo* (pp.94-96). Stead (1963 p.149) regards *T. macneilli* as conspecific with *T. fairchildi* Hutton.

The characters separating *T. macneilli* from the New Zealand *T. fairchildi* appear to be:

(1) Spiracles closer to orbits.
(2) Disc not as circular.
(3) Rear end of the base of the first dorsal fin considerably posterior to the rear ends of the pelvic fin bases.

Distribution. New South Wales, Victoria, South Australia and southern Western Australia. Not represented in the Western Australian Museum.

Genus *NARCINE* Henle

Narcine Henle 1834 p.2; type species *Torpedo brasiliensis* Olfers 1831.
Syrraxis Jourdan 1841; type species *Narcine indica* Henle 1834.
Cyclonarce Gill 1862 p.387; type species *Narcine timlei* Henle = *Raja timlei* Bloch & Schneider 1801.
Gonionarce Gill 1862 p.387; type species *Narcine indica* Henle 1834.
Heteronarce Regan 1921 p.414; type species *Heteronarce garmani* Regan 1921.
Narcinops Whitley 1940 p.164; type species *Narcine tasmaniensis* Richardson 1840.

Diagnosis. Disc rounded, shorter or slightly longer than tail. Tail moderate, with well developed lateral cutaneous folds. Caudal fin ovate or truncate. Two dorsal fins, the first originating over or slightly behind ends of pelvic fin bases. Pelvic fins distinct, their outer margins broadly rounded or concave, posterior margins not joined across base of tail. Snout produced, rostral cartilage broad and shovel-shaped, somewhat flexible near tip, with or without a transverse foramen in proximal portion. Mouth narrow, transverse, protractile as a short tube; upper and lower jaw cartilages bound together by two triangular labial cartilages which limit gape of mouth. Teeth in narrow bands only loosely attached to jaw cartilages, and extending well out on to upper and lower lips. Nostrils not divided by a cross-bridge, almost roofed over by a joint nasal curtain which extends to or almost to mouth. Nasal curtain almost as broad as deep in some species, much broader than deep in others. Eyes developed, smaller than spiracles in some species, larger than spiracles in others. Spiracles contiguous to eyes or only slightly separate; margins smooth, corrugated, or bearing papillae.

The following species are recognised by the author.

- *Narcine timlei* (Bloch & Schneider) 1801.
- *Narcine brasiliensis* (Olfers) 1831.
- *Narcinc indica* Henle 1834.
- *Narcine tasmaniensis* Richardson 1840.
- *Narcine lingula* Richardson 1846.
- *Narcine mollis* Lloyd 1907.
- *Nacine brunnea* Annandale 1909.
- *Narcine garmani* (Regan) 1921.
- *Narcine vermiculatus* Breder 1928.
- *Narcine schmitti* Hildebrand 1948.
- *Narcine westraliensis* sp. nov.

Comments. In their recent revision of the Torpedinidae, Bigelow and Schroeder (1963 pp.87-132) consider *Syrraxis, Cyclonarce, Gonionarce,* and *Narcinops,* synonms of *Narcine,* and remarked (p.89 footnote) . . . "*Heteronarce* is so close to *Narcine* that its generic validity is doubtful . . . " In keys to the Torpedinidae given by Fowler (1941 p.332), and Bigelow and Schroeder (1953 pp.87-90), *N. westraliensis* sp. nov. would key down to *Heteronarce.*

The key character recognised by previous authors for *Heteronarce* is the relatively narrow nasal flap. *N. westraliensis* has this narrow nasal flap but in most other features resembles species belonging to *Narcine,* particularly *N. tasmaniensis. Heteronarce* is here synonymised with *Narcine,* the concept of which has been broadened.

Narcine westraliensis species nova
(Figs. 3, 4, 5, 6)

The description is based on the holotype, a male of 212 mm total length, W.A.M. P 6963, collected by author October 5, 1960, 8 miles N.W. of Cape Peron, Shark Bay, Western Australia. The range given within the parenthesis is the percentage of the total length of 43 paratypes listed below.

Description. Disc subcircular, anterior margin evenly rounded. Length of disc slightly less than breadth (equal to or slightly greater than breadth in most paratypes) 40.6% of total length, (38.7-41.6 in males, 36.9-44.1 in females). Posterior contour of pectorals rounded and recurved, merging with sides of tail. Tail moderately rounded above, slightly flattened below, tapering to caudal fin, length from centre of cloaca 55.7% of total length (52.3-58.3), and greater than distance between snout tip and centre of cloaca. Tail with a narrow, low cutaneous fold originating below first dorsal fin, and continuing 25.9% of total length (20.1-29.0).

Length of snout in front of orbits 8.9% (7.1-10.4) of total length. Orbits prominent and elevated, larger than spiracles; longitudinal diameter of orbit 47.4% of snout length (38.8-58 8 in males, 38.9-50.0 in females) and 81.8% of interorbital space (53.8-90.0 in males, 57.1-72.7 in females). Width of orbits 54.5% of interorbital space (35.7-70.0 in males, 35.3-59.1 in females).

Spiracles contiguous to eyes; margins smooth, only slightly raised, without papillae. Length of spiracle from posterior of orbit 42.9% (28.6-46.1 in males, 26.7-50.0 in females) of distance between spiracles.

Snout tip to anterior margins of nostrils 8.5% (7.7-9.6) of total length. Nostrils small, almost transverse interiorly, rounded exteriorly. *Nasal flap or curtain narrow with rounded corners, straight behind without projections or lobes, free edge entire, without fringes.* Depth of nasal curtain 85.0% of its least width (65.0-92.9 in males, 68.8-100.0 in females. Nostrils without outer flaps or lobes.

Mouth transverse, straight, somewhat protractile; extreme breadth 7.6% (6.0-8.5) of total length. Lips fleshy and wrinkled.

Teeth somewhat rhomboidal in shape, inner ones with posterior angle produced to form an acuminate cusp. (Tooth rows increasing with growth, from 6/6 in embryo of 63 mm t.l., to 22/21 in female of 266 mm t.l., see Fig.4). Tooth bands extend outside mouth (see Fig.5a). Behind teeth of both jaws, a raised fimbriate fleshy ridge is present, followed by transverse, raised, cutaneous ridges lacking projections in the midline.

Snout tip to origin of first dorsal fin 55.7% of total length (52.1-57.1 in males, 50.5-57.9 in females). Snout tip to origin of second dorsal fin 70.3% of total length (66.8-71.8 in males, 65.3-74.1 in females). Dorsal fins, similar in shape, apex rounded, little change with growth. Origin of first dorsal fin over posterior end of pelvic base. First dorsal fin vertical height 8.5% of total length (7.2-10.0 in males, 6.0-9.6 in females); second dorsal fin vertical height 8.0% of total length (7.5-10.2 in males, 6.3-9.8 in females). First dorsal fin base 7.6% of total length (6.9-9.0 in males, 6.9-8.3 in females); second dorsal fin base 8.5% of total length (7.8-9.6 in males, 8.0-9.2 in females) Interdorsal space 5.2% of total length (5.1-8.3 in males, 5.0-7.2 in females).

Caudal fin ovoid, upper and lower margins continuously rounded, without definite lower corner. Length of caudal fin from origin of lower margin 17.7% of total length (17.7-19.5 in males, 16.7-20.3 in females).

Pectoral fins overlapping origin of pelvic fins. Outer margin of pelvic fins almost straight (weakly concave to weakly convex). Inner margins of pelvics anterior to rear tips, free from sides of tail for a short distance.

Height of body 9.4% of total length (8.0-11.1 in males, 7.5-13.5 in females). Gill openings small, increasing slightly in length from first to fourth; fifth gill slit smallest.

Body light buff or sandy with rather ornate, variable brown markings on disc. (Pattern frequently in the form of transverse bars or bands of varying width, or vague chain-like markings). Tail with transverse bars in all specimens including embryos. Colour never uniform brown above. Undersurface light, almost white. Eyes black.

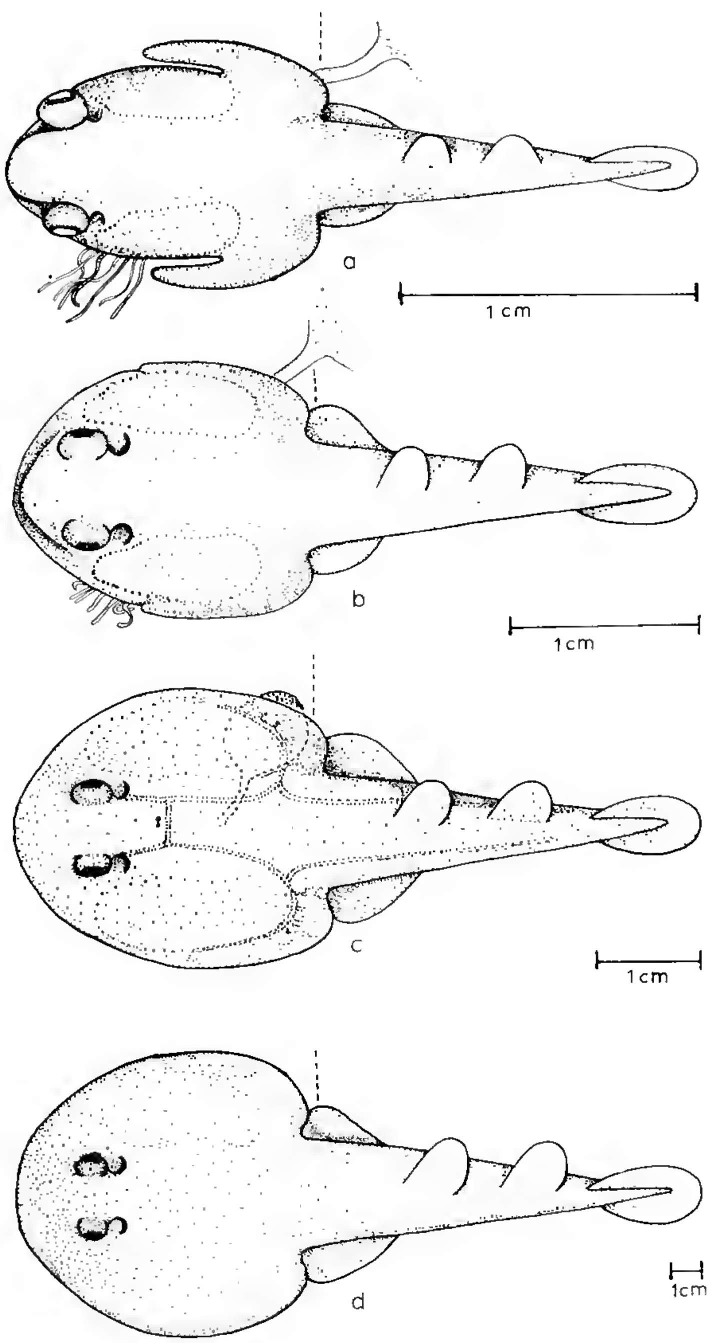


Figure 3.—*Narcine westraliensis* sp. nov. selected specimens showing changes in body proportions with increase in size. All are drawn to same size for comparison. a: embryo P 7721, total length 23.2 mm; b: embryo P 7726, total length 38.6 mm; c: embyro P 7734, total length 66.5 mm; d: adult male, total length 212 mm.

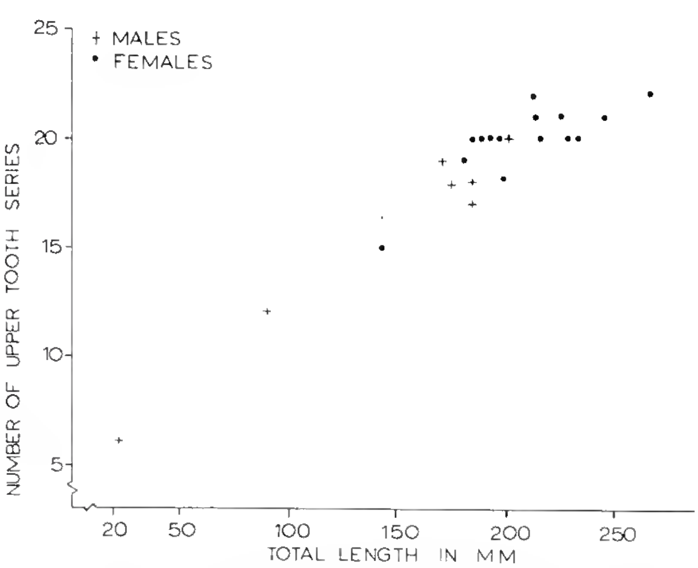


Figure 4.—Scatter diagram showing increase in number of upper tooth series with increase in body size for male and female *Narcine westraliensis*.

Comparison of N. westraliensis with other species

Registered material examined in Western Australian, Australian, and Bombay Museums is prefixed W.A.M., A.M., and B.M. respectively.

Narcine westraliensis

Paratypes. 21 males and 22 females trawled inside Shark Bay by State Fisheries Research Vessel *Peron* during years 1960 and 1962: W.A.M.
P 6946 ♂ 209 mm t.l., P 6947 ♂ 176 mm t.l.,
P 6948 ♀ 212 mm t.l., P 6949 ♀ 190 mm t.l.,
P 6950 ♀ 268 mm t.l., P 6951 ♂ 203 mm t.l.,
P 6952 ♀ 189 mm t.l., P 6953 ♀ 184 mm t.l.,
P 6954 ♂ 186 mm t.l., P 6955 ♂ 174 mm t.l.,
P 6956 ♂ 187 mm t.l., P 6957 ♂ 180 mm t.l.,
P 6958 ♂ 195 mm t.l., P 6959 ♂ 200 mm t.l.,
P 6960 ♀ 110 mm t.l., P 6961 ♂ 182 mm t.l.,
P 6962 ♂ 201 mm t.l., P 6964 ♀ 207 mm t.l.,
P 6965 ♀ 160 mm t.l., P 6966 ♂ 195 mm t.l.,
P 6967 ♂ 184 mm t.l., P 6968 ♀ 193 mm t.l.,
P 6969 ♂ 157 mm t.l., P 6970 ♂ 202 mm t.l.,
P 6971 ♂ 204 mm t.l., P 6972 ♀ 180 mm t.l.,
P 6973 ♂ 117 mm t.l., P 6974 ♀ 195 mm t.l.,
P 6975 ♂ 193 mm t.l., P 6996 ♀ 182 mm t.l.,
P 6997 ♂ 197 mm t.l., P 6998 ♀ 190 mm t.l.,
P 6999 ♀ 188 mm t.l., P 7003 ♀ 196 mm t.l.,
P 7004 ♀ 189 mm t.l., P 7005 ♂ 190 mm t.l.,
P 7009 ♀ 198 mm t.l., P 7016 ♀ 222 mm t.l.,
P 7018 ♀ 238 mm t.l., P 7031 ♀ 220 mm t.l.,
P 7033 ♀ 195 mm t.l., P 7035 ♂ 194 mm t.l.,
P 5027 ♀ 200 mm t.l.

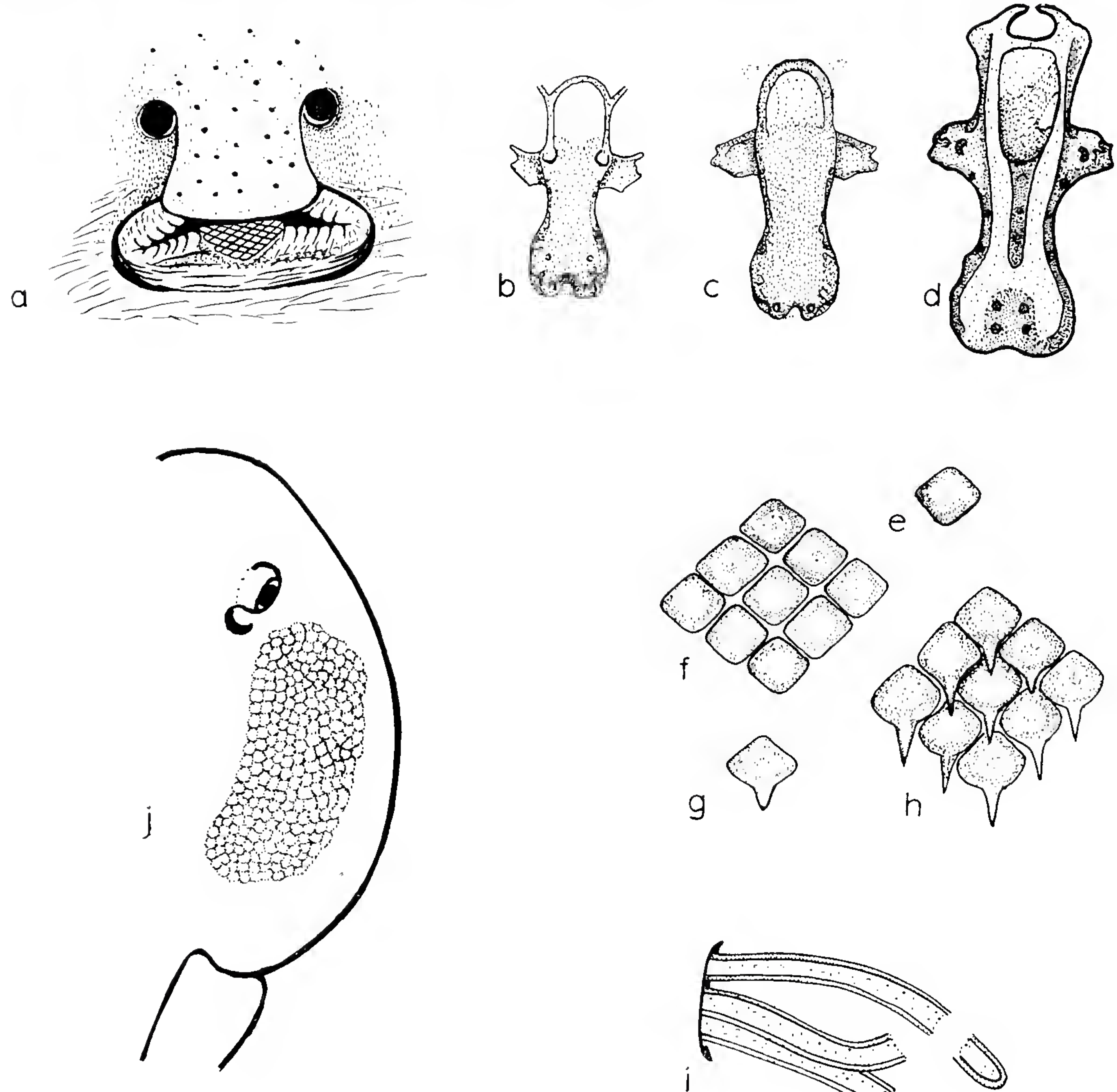


Figure 5.—a: *Narcine westraliensis* mouth and nasal curtain; b: *Narcine westraliensis* skull (from radiograph); c: *Narcine tasmaniensis* skull (from radiograph); d: *Narcine brasiliensis* skull (after Henle); e: External teeth of *Narcine tasmaniensis;* f: External teeth of *Narcine tasmaniensis;* g: Inner-most teeth of *Narcine tasmaniensis;* h: Inner-most teeth of *Narcine westraliensis;* i: Filamentous gills of *Narcine westraliensis* embryos; j: *Narcine westraliensis* showing position of electric organ on one side of disc.

W.A.M. P 6978-P 6993, 16 specimens, some dissected. 21 embryos W.A.M. P 7720 ♀ 36.0 mm t.l., P 7721 sex ? 23.2 mm t.l., P 7722 sex ? 23.3 mm t.l., P 7723 ♀ 36.8 mm t.l., P 7724 ♀ 38.1 mm t.l., P 7725 ♀ 38.5 mm t.l., P 7726 ♂ 38.6 mm t.l., P 7728 ♂ 55.0 mm t.l., P 7729 ♀ 63.6 mm t.l., P 7730 ♀ 61.0 mm t.l., P 7732 sex? 25.7 mm t.l., P 7733 ♀ 59.0 mm t.l., P 7734 ♀ 66.5 mm t.l., P 7797 ♂ 60.0 mm t.l., P 7798 ♀ 53.5 mm t.l., P 7799 ♀ 63.0 mm t.l., P 7800 ♂ 40.0 mm t.l., P 7801 ♀ 64.0 mm t.l., P 7810 ♂ 60.0 mm t.l., P 7851 ♀ 46.0 mm t.l., P 7853 ♀ 47.0 mm t.l.

Embryos in Table 1

Group A.	3 specimens W.A.M. P 7721, P 7722, P 7732, 23.2 mm t.l. to 25.7 mm t.l.
Group B.	5 specimens W.A.M. P 7720, P 7723, P 7724, P 7725, P 7726, 36.0 mm t.l. to 38.6 mm t.l.
Group C.	3 specimens W.A.M. P 7800, P 7851, P 7853, 40.0 mm to 47.0 mm t.l.
Group D.	5 specimens W.A.M. P 7798, P 7733, P 7728, P 7810, P 7797, 53.5 mm to 60.0 mm t.l.
Group E.	5 specimens W.A.M. P 7801, P 7799, P 7734, P 7729, P 7730, 61.0 mm to 66.5 mm t.l.

Other Narcine *species*

N. tasmaniensis A.M. IB 4751 male 254 mm t.l., collected Miss J. Campbell, Bermagui N.S.Wales, 14.viii.1960. A.M. IB 4752 female 224 mm t.l., data as above specimen. A.M IB 4330 female 110 mm t.l., collected by Dr. A. A. Racek, N.E. Broken Bay, N.S.Wales 19.vi.1959, 137 fathoms. A.M. I 9982 female 225 mm t.l., collected F.R.V. "Endeavour" east of Flinders Island, Bass Strait, vi.1909. A.M. IA 2968 three foetal specimens 75 mm to 92 mm t.l., all females, collected A. Ward, off Port Hacking, N.S.Wales, 40-50 fathoms, x.1926.

N. timlei A.M. I 135 female 167 mm t.l., purchased Mr. F. Day, ii.1886, Madras A.M. I 49 female 203 mm t.l., data as above specimen. B.M. 88.11.67, male 300 mm t.l. B.M. 88.11.6.87.89, female 288 mm t.l.

N. indica B.M. 1367 male 280 mm t.l.

Narcine westraliensis differs from *N. garmani* (originally *Heteronarce*) in having head approximately 7 in total length ($5\frac{1}{3}$ in (*N. garmani*) in having snout 7.2 - 10.4% of total length instead of about 11.7%, the diameter of the eye in *N. westraliensis* ranges from 38.8%-58.8% of snout length, whereas in *N. garmani* eye is about 20% of snout length. *N. westraliensis* has a shorter snout; the posterior edge of the nasal flap is regular, outer margins of pelvics not convex, and the caudal fin is ovoid, not fan-shaped. Colour not uniform above as in *N. garmani*.

From N. *mollis* (the other species formerly placed in *Heteronarce*) *N. westraliensis* differs in having disc less than half total length; smaller spiracles without a raised ridge on margin; nasal curtain with rounded corners and no projection in mid-line; nostrils transverse, without a surrounding flap of tissue as shown by Lloyd (1909 pl.XLVI Fig.1a). The caudal fin is ovoid and not fan-shaped as in *N. mollis*. Colour not uniform above.

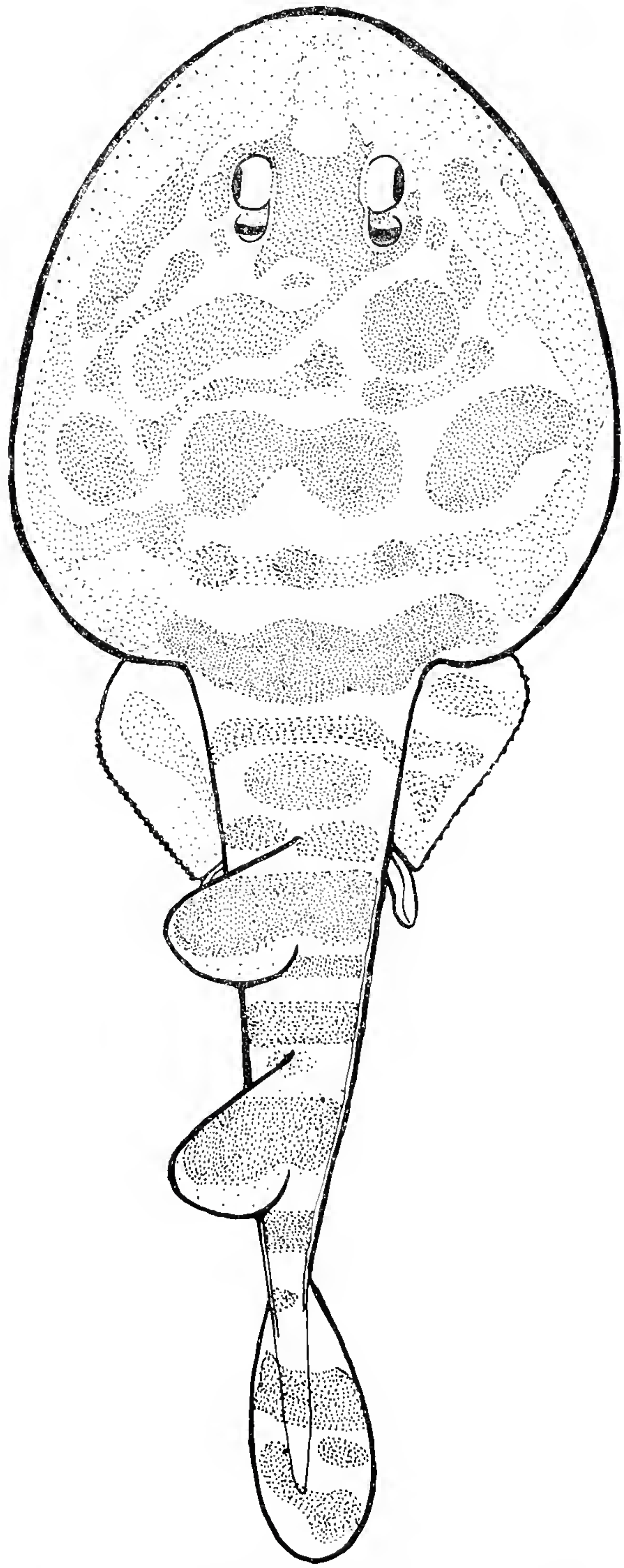


Figure 6.—*Narcine westraliensis.* Holotype P 6963, total length 212 mm.

From other species of the genus *Narcine*, *N. westraliensis* can be distinguished by its colour pattern, and narrower nasal curtain, but apart from these characters it differs from *N. brasiliensis* in having tail ovoid instead of fan-shaped, less numerous teeth series, spiracles with smooth margins, fewer columns in electric organs, and appears to be smaller; from *N. vermiculatus* in having ovoid caudal fin, eyes larger than spiracles, having a slightly smaller snout than figured by Breder (1928 Fig.3, Fig.4), and having dorsal fins more separated; from *N. lingula* in having ovoid caudal fin, eyes larger than spiracles, having a slightly smaller snout than figured by Breder (1928 Fig.3, Fig.4), and having dorsal fins more separated; from *N. lingula* in having ovoid caudal fin, eyes larger than spiracles, fewer teeth series, entirely smooth spiracles, disc longer than wide, and dorsals not rather pointed; from *N. schmitti* in having ovoid caudal fin, smaller disc, and much shorter snout; from *N. indica* in possessing smaller spiracles, shorter dorsal fins, and greater inter-dorsal space; from *N. timlei* in having smaller disc, much smaller snout, larger eyes, smaller spiracles and in having posterior tips of pelvics free from tail for a short distance; and from *N. brunnea* in those features listed for *N. timlei* and having nasal curtain without a projection in the mid-line.

In comparison with *N. tasmaniensis*, *N. westraliensis* shows the following differences:

(1) The nostrils are closer together, thus resulting in a much narrower nasal curtain.

(2) Coloration is never a uniform brown above.

(3) The second dorsal fin is slightly closer to the origin of the caudal fin.

(4) The spiracles are quite contiguous in all examples, whereas in *N. tasmaniensis* some large examples appear to have the spiracles slightly separate from the eyes. Richardson's (1849 Pl.XI Fig.2) figure of *N. tasmaniensis* shows eyes quite remote from spiracles, and he gives distance between spiracles and eyes as exceeding "the quarter of the space between the eyes."

Whitley (1940, Figs. 180 and 186) show spiracles contiguous with eyes, and this is confirmed for most specimens examined by me, particularly smaller examples.

(5) The nasal curtain of *N. westraliensis* has significantly more pores studding its surface (about 15) than does *N. tasmaniensis* (about 2 or 3).

Regan (1921 p.414), when proposing the genus *Heteronarce*, used the occurrence of numerous pores on the nasal flap of *N. garmani* as a generic character. Lloyd 1909 pl.XLVI, Fig.1a) shows the nasal flap of *N. mollis* with numerous pores. Fowler (1925 p.198), in describing *Narcine natalensis* (= *N. garmani*) made no mention of nasal flap pores, and von Bonde and Swart (1923 p.15) in describing *Heteronarce regani* (= *N. garmani*) state that their specimen "agrees in all features with the generic characters of *Heteronarce* Regan, except that the naso-frontal lobe is not studded with pores."

The occurrence of numerous nasal-flap pores in other species is yet to be determined, as they are inconspicuous and can easily be overlooked.

Internal anatomical observations. Whitley (1940 p 164) proposed the genus *Narcinops* on the basis that *N. tasmaniensis* differed from the typical *Narcine* (*N. brasiliensis*) "in form of body, margin of nasal valves, in having a wider skull and different cartilages, as discovered by Richardson" (1849 p.180).

I agree with Richardson that the skull in *N. tasmaniensis* is proportionately wider than Henle's (1834 Pl.IV Fig.1) figure of the skull of *N. brasiliensis*, that the small intermediate cartilages between antorbital and rostral cartilages are lacking, and that the foramen in the anterior part of the rostral cartilage is absent; but I do not agree with Whitley that these are of generic importance.

All examples of *N. westraliensis* radiographed are without a foramen in the anterior portion of the rostral cartilage, lack the small intermediate cartilage between antorbital and rostral carilages and possess a proportionately wider skull than that figured for *N. brasiliensis* (see Figs. 5 b, c, d).

Richardson (1849 p.180), recorded 118 vertebrae for *N. tasmaniensis*, and for that species (A.M. IB 4751) I count 122. Vertebral counts for specimens of *N. westraliensis* were: W.A.M. P 6952, 107; W.A.M. P 6970, 100; W.A.M. P 6971. 103: W.A.M. P 6972, 102; W.A.M. P 6973, 109; W.A.M. P 6974, 103; W.A.M. 6975, 107.

All radiographed specimens have the first 13 or 14 vertebrae with quite short transverse processes, the next 6 or 7 have transverse processes very long and slender. Specimens W.A.M. P 6952, P 6970 and P 6971 have 5 on one side, 6 on the other. Specimens W.A.M. P 6972. P 6974 and P 6975 have 6 plus 7. In *N. tasmaniensis* A.M. IB 4751 I count 7 plus 7.

Both *N. westraliensis* and *N. tasmaniensis* have short conical spines near posterior internal margins of spiracles, these number from 3 to 7 on each side, individual counts for *N. westraliensis* were ♂ 171 mm t.l., 3 + 3, ♂ 175 mm t.l., 3 + 4, ♂ 181 mm t.l., 4 + 4, ♀ 194 mm t.l.. 4 + 4. ♀ 196 mm t.l., 7 + 5, ♀ 248 mm t.l., and ♀ 266 mm t.l., 6 + 6. *N. tasmaniensis* ♂ 254 mm t.l. had 4 + 4.

The pelvic fins in *N. tasmaniensis* (A.M. IB 4751) have 19 cartilaginous rays (including clasper) whereas Richardson (1849 p.181) gives 21. In *N. westraliensis* specimens I find 17 to 19.

Teeth. Figure 4 shows the increase of tooth rows in the upper jaw with growth of *N. westraliensis* specimens. Counts of tooth rows in upper and lower jaws are generally the same but some specimens possess one or two more in upper jaw.

The shape of the innermost and outermost teeth differs markedly as shown by Figs. 5 f, h, the innermost teeth possessing an elongate sharply pointed cusp on lower angle. Since the shape of the teeth is similar in late stage embryos, differences are not due to wear.

Biometrical observations. Table 2 gives the biometrics of *N. westraliensis* adults and embryos and the adults of *N. tasmaniensis*. The values are given as arithmetic means expressed in thousandths of the total length unless stated otherwise.

Regression equations and correlation coefficients for three important dimensions are given separately for 22 adult male and 22 adult female *N. westraliensis*. The statistics and symbols of Simpson, Roe and Lewontin (1960) have been adopted. Males: size range 117 mm t.l. to 212 mm t.l.

The regression of the dimension snout tip to cloaca centre (Y) on the total length (X) is given by the equation Y = 0.434X + 1.41, the confidence limits at the 95% level being ± 0.046 and ± 0.91 for Byx and Ay. Confidence limits at any level can be obtained for the mean and individual predicted value of Y using the values Syx = 2.055, Sx^2 = 414.95, $\bar{x}$ = 188. The correlation of Y and X is very high, r = 0.975, z = 2.185.

The regression of the dimension snout tip to origin of the first dorsal fin (Y) on the total length (X) is given by the equation Y = 0.528X + 3.72, the confidence limits at the 95% level being ± 0.058 and ± 1.15. Syx = 2.588. The corection of Y and X is r = 0.972, z = 2.078.

The regression of the dimension snout tip to pectoral axilla (Y) on the total length (X) is given by the equation Y = 0.394X + 1.66, the confidence limits at the 95% level being ± 0.047 and ± 0.94. Syx = 2.123. The correlation of Y and X is r = 0.968, z = 2.060.
Females: size range 110 mm t.l. to 268 mm t.l.

The regression of the dimension snout tip to cloaca centre (Y) on the total length (X) is given by the equation Y = 0.454X — 2.18, the confidence limits at the 95% level being ± 0.037 and ± 1.08 for Byx and Ay. Confidence limits at any level can be obtained for the mean and individual predicted value of Y using the values Syx = 2.434, Sx^2 = 863.23, $\bar{x}$ = 196. The correlation of Y and X is very high. r = 0.984, z = 2.410.

The regression of the dimension snout tip to the origin of the first dorsal fin (Y) on the total length (X) is given by the equation Y = 0.568X — 2.42, the confidence limits at the 95% level being ± 0.036 and ± 1.06. Syx = 2.372. The correlation of Y and X is r = 0.991, z = 2.700.

The regression of the dimension snout tip to pectoral axilla (Y) on the total length (X) is given by the equation Y = 0.395X + 2.00, the confidence limits at the 95% level being ± 0.055 and ± 1.58. Syx = 3.561. The correlation of Y and X is r = 0.960, z = 1.946.

TABLE 2

Biometrical measurement of Narcine westraliensis *and* Narcine tasmaniensis.

	N. westraliensis Embryo's Group A	*N. westraliensis* Embryo's Group B	*N. westraliensis* Embryo's Group C	*N. westraliensis* Embryo's Group D	*N. westraliensis* Embryo's Group E	*N. westraliensis* Adult males	*N. westraliensis* Adult females	*N. tasmaniensis* Adult male	*N. tasmaniensis* Adult females
NUMBER OF SPECIMENS MEASURED	3	5	3	5	5	22	22	1	3
Snout tip to pectoral axilla	446	414	424	444	439	402	402	386	399
Greatest width of disc	358	397	400	411	441	386	379	394	423
Snout tip to line before orbits	59	72*	82	87	91	89	89	91	94
Snout tip to anterior of nostrils	99	93	86	97	91	87	84	75	87
Snout tip to origin of 1st dorsal fin	571	549	538	549	548	550	550	531	549
Snout tip to origin of 2nd dorsal fin	617	670	655	681	674	693	697	677	689
Interorbital space	105	91	78	72	70	58	60	55	60
Distance between spiracles	127	110	94	90	87	69	69	63	67
Greatest width of mouth	69	68	59	61	63	72	72	63	61
Vertical height of 1st dorsal fin	43	59	60	67	65	84	79	75	72
Vertical height of 2nd dorsal fin	46	65*	59	66	64	84	80	67	75
Basal length of 1st dorsal fin	71	70	66	73	71	79	78	71	73
Basal length of 2nd dorsal fin	78	83	77	79	74	87	85	71	75
Distance between dorsal fins	57	52	50	66	58	65	62	87	78
Snout tip to cloaca centre	451**	457	443	438	439	414	441	433	443
Height of body	124	127	114	114	119	96	99	71	85
Length of tail keel	245*	.	....	...	...	239	243	280	300
Caudal fin length	.	...	193	191	185	185†	178†	177	...

All above measurements expressed as thousandths of total length.

Diameter of orbit in interorbital	787	729	753	784	822	722	645*	714	692
Width of orbit in interorbital ...	614*	546	591	586	582	510	498*	571	538
Length of spiracles in interspiracular	219	229	273	284	315	372	362	438	400
Width of spiracles n interspiracular	165	225	265	291	298	341	320	438	377
Orbit of eye in snout (before orbits)	1349	926	722	638	631	473	436	435	420
Length of nasal flap in its width	467	659	697	856	921	767	851	357	360**
Mouth width in snout length ...	1157	896	731	697	727	827	820	696	....

All above proportions expressed as thousandths.

* = 1 specimen less. ** = 2 specimens less. † = 12 specimens less.

TABLE 3

Narcine westraliensis

Number of columns in electric organ

Total length	Sex	Left side	Right side
164 mm.	♀	....	208
169 mm.	♀	196	....
180 mm.	♂	207	202
181 mm.	♀	198	....
184 mm.	♂	214	216
185 mm.	♀	....	197
193 mm.	♂	....	198
195 mm.	♂	212	220
206 mm.	♀	204	....

Electric organs and capcbilities. The development of the electric organs occurs at a very early stage; the columns are readily observable in specimens of 20 mm t.l., and are almost fully developed well before birth. Figure 5j shows position of these organs. Nine specimens were dissected and counts of the number of columns per organ were made; these counts are given in Table 3.

Attempts to induce late stage embryos to discharge were unsuccessful. Cox and Breder (1943 p.48) had difficulty in making adult *Narcine brasiliensis* discharge, and I noticed that *N. westraliensis* was similarly reluctant, and allowed other fishes such as flounder (*Pseudorhombus* sp.) and flying gurnards (*Dactyloptena orientalis* Cuvier and Valenciennes) to settle on them. Adult *Narcine* could be gently handled underwater without receiving electric shocks, but the fish often discharged when first removed from the water. Only occasionally did a large *Narcine* produce a shock sufficiently powerful to discourage handling. As these fish were exhausted after 3 or 4 discharges it was not surprising to find *Narcine* incapable of producing shocks when removed from amongst the catch of the trawl net (the fish had probably exhausted its powers on contact with the trawl net when first captured).

General developments. Figure 3 shows the development of *N. westraliensis,* (a) an embryo, P 7721, 23.2 mm in total length, (b) an embryo, P 7726, 38.6 mm in total length. (c) an embryo, P 7734, 66.5 mm in total length, (d) an adult male 212 mm in total length. Drawn to same scale for comparison.

The smallest embryos obtained measured 19 mm in t.l., and at this size differ considerably from the late stage embryos in having the pectoral fins quite separate from the body; the mouth is rather poorly developed; eyes are relatively much larger; snout is a raised prominence; spiracles are small and covered over by semi-transparent tissue; the nasal openings are almost completely covered by a flap; the tail keel is absent; electric organs are just developed; the dorsal fins, although present have not assumed adult shape; the gills are external, three filaments arise from each gill opening, and extend well past cloaca, the filaments are shown in Figure 5 i.

At 20-22 mm t.l., the tail keel commences to form, and the pectoral fins are closer to the body. Figure 3 a shows specimen W.A.M. P 7721 (23.2 mm t.l.); the tail keel is almost developed at this stage; the pectoral and pelvic rays are unbranched at their extremities; no trace of nuchal pores are present, and colour pattern has not emerged.

Embryo W.A.M. P 7805 (25 mm t.l.) has the nuchal pores just present and shows early development of the mucous canal system.

Embryo W.A.M. P 7849 (a female of 35 mm t.l.) has the beginnings of the characteristic colour pattern; the pectoral and pelvic radials show recent branching at their tips, and fusion of the pectorals is well advanced.

Figure 3 b shows embryo P 7726 (a male of 38.6 mm t.l.), only a slight notch remains on side of disc; the spiracle has almost lost the sealing flap of tissue; the snout is not as prominent; the colour pattern is visible and dorsal fins have developed further. The yolk sac measures about 16 mm in diameter.

The spiracles are fully open in embryos of 40-42 mm, the mouth shows much development, and colour pattern is almost established. External gills are still in evidence until the embryo measures 54 mm in t.l. (W.A.M. P 7856), and the yolk sac persists until a length of 63.5 (W.A.M. P 7081) to 66 mm is reached.

The teeth originate in embryos between 60 and 65 mm total length. Size at birth is approximately 75 mm t.l. Bigelow and Schroeder (1953 p.118) give average length at birth for *N. brasiliensis* as about 110-120 mm.

Female *N. westraliensis* mature at about 180 mm t.l.; one female of 155 mm t.l. was exceptional in having enlarged ovarian follicles. Gravid females were taken throughout the year, but the main breeding season extends from May to November, with peak activity during September and October. Many gravid females were collected and examined, and from one to eight embryos were recorded. Embryos within the one female were sometimes found to be in various stages of development, and some females had late stage embryos positioned for birth whilst very early stage embryos were to be found higher in the oviduct. This observation may partly explain the rather extended breeding season.

It was noticed that gravid females would often have male embryos only in one oviduct, and female embryos in the other. Breder and Springer (1940) noted that in *N. brasiliensis*, small females produced proportionally more female offspring and large females produced proportionally more male offspring; this was not observed in *N. westraliensis*.

Stead (1963 p.149) believed that the electric organs of female electric rays would be inactive during parturition. At birth (75 mm), the embryos of *N. westraliensis* have well developed electric organs, and it is just as likely that any electric stimulation given to an embryo at parturition would not be harmful to it and the embryo would not be given a "lively time" as Stead suggests. Although no gravid females of *N. westraliensis* were actually tested for shocks during parturition, females containing developing embryos certainly did produce shocks.

The inner walls of the uterus in a gravid female *N. indica* have been illustrated by Prashad (1920 pl.vii Fig.4). He reports the entire inner surface to be covered with spatulate villi-like trophonemata, and remarks (p 104) "the covering of trophonemata is so thick that no part of the uterine wall is to be seen between them. In a square inch of wall of the preserved uterus 198 villi were counted." Prashad also mentioned "that the uterus was full of a yellowish milk-like secretion in which the embryos were enclosed."

In all the gravid female *N. westraliensis* examined, the inner walls of the uterus are entirely without a covering of villi, being quite thin, membranous, almost transparent, with an occasional vein across the surface. The embryos within could be easily discerned through the uterine wall.

The uterus contained a clear fluid, quite unlike that described by Prashad for *N. indica*, although this fluid became yellowish and milk-like when the contents of the easily ruptured embryonic yolk sac were set free.

The young appear to be born tail first, and late-stage embryos are often in this position within the uterus. Prematurely born embryos of 60-73 mm t.l. were occasionally found amongst trawl contents on the trawling vessels.

The largest *N. westraliensis* measured by the author was a female of 293 mm t.l.

Habits. As with other electric rays, *N. westraliensis* is a somewhat sluggish, bottom-dwelling fish. It swims away if forcefully disturbed, but often remains stationary, even permitting gentle handling without attempting to escape.

Four adults were sent to Perth by air, and held alive in a marine aquarium for a period of three months. For the following observation I am indebted to Mrs. Munday of Cottesloe. W.A.

"The *Narcine* were often seen to be covering themselves with sand, only the eyes and spiracles remained visible. They could bury themselves rapidly by moving sideways and agitating their bodies, and normally remained covered by sand for most of the day, swimming around in search of food during dusk and early morning. Scraps of fish flesh and crushed terrestrial snails were eaten." The gut contents of 9 adult *N. westraliensis* taken from the trawl contents were examined and contained annelid worms.

Distribution and ecology. Nareine westraliensis was often taken by trawl net inside Shark Bay. It was common on commercial prawn (*Penaeus* sp.) trawling grounds, and especially abundant in areas where the bay scallop *Amusium balloti* Bernardi occurred. In spite of extensive trawling in the Exmouth Gulf area by research vessels "Lancelin" and "Peron" no *Nareine* were taken. *N. westraliensis* appears to be restricted to Shark Bay. The depths at which this little numbfish was found ranged from 6 fathoms to 17 fathoms. Areas outside the depth range given above were rarely trawled.

Although preferring a salinity of about 38.80‰ *N. westraliensis* was found to be present in waters varying in salinity from 36.13‰ to 44.00‰ Bottom temperatures ranged from 17.8°C to 22.8°C.

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10.—A new fish of the family Apogonidae from tropical Western Australia

by G. F. Mees*

Manuscript received 16th February, 1965; accepted 22nd June, 1965

Abstract

Quinca mirifica gen. et sp. nov., of the family Apogonidae, differs from all other members of the family in that there are fourteen rays in the dorsal fin; a maximum of ten has hitherto been regarded as a family characteristic. The holotype and only specimen was collected from Cockatoo Island, tropical Western Australia. In most respects it is close to *Apogon*.

Amongst the fishes which the late Mr. G. A. Robinson of Cockatoo Island, Yampi Sound, collected for the Western Australian Museum, is a single specimen that, though undoubtedly belonging to the Apogonidae, shows some aberrant characters, on the basis of which I feel fully justified in describing it as a new species representing a new genus.

Genus Quinca gen. nov.

Diagnosis. Characterized by the long second dorsal fin, which has fourteen soft rays. No other genus of the family has more than ten dorsal rays. Ventral fins very long, reaching to well beyond the origin of the anal fin.

Type of the genus:

Quinca mirifica sp. nov.

D VII-I.14, A II.13, P ii.12.ii, V 1.5, Cii.15.ii, pore bearing scales in lateral line 25+2, gillrakers on outer branchial arch 3+1+13, of which the last five rudimentary.

In general appearance a typical member of the Apogonidae, total length 105 mm, standard length 80 mm, greatest depth of body 35 mm, length of head 31 mm, length of P 23 mm, length of V 30 mm, length of snout 8 mm, diameter of eye 10 mm, width of interorbital 8½ mm.

Head large, about 2.5 in standard length, eye large, snout slightly shorter than eye.

Mouth large, maxillary reaching to below posterior border of pupil, upper edge of maxillary concealed under praeorbital when mouth is closed, posterior nostril fairly large, oval, in front of middle of eye, anterior one much smaller, lower, near tip of snout and only a little above pracmaxilliary; praeorbital fairly narrow, its width less than half an eye's diameter; posterior border of praeoperculum almost smooth, posterior border of interoperculum finely serrated, posterior border of operculum without spines, unless a short flat projection just above the level of the middle of the eye be called such.

Dentition complete, teeth in jaws in villiform bands; similar teeth on vomer and palatines; no canines. Tongue steadily narrowing towards the tip, ending in an obtuse point.

Lateral line complete, evenly following the curve of the back, and straightening out on the caudal peduncle; pore bearing scales twenty-five, and two more on the basis of the tail.

Scales cover the whole body, but of the head only the opercles, including praeoperculum; nape naked and covered with skin which in the preserved specimen shows londitudinal striae, to only a little distance in advance of the first dorsal fin. A single scale is, however, present above the posterior part of the eye.

There are two entirely separated dorsal fins, the first one consisting of seven spines, the second with one spine and fourteen divided rays. Length of basis of D_1 10½ mm, of D_2 19 mm, intervening gap 4 mm.

The spines are of moderate strength. The length of the spines of D_1 is: I, minute; II, 8 mm; III, 14½ mm; IV, 15 mm; V, 13 mm; VI, 9 mm, VII, 4 mm. The spine of D_2 measures 15 mm; D_2 is rounded with the 4th and 5th rays longest, 27 mm, and subsequent rays decreasing in length towards the last one which is 11½ mm.

The anal fin consists of two spines and thirteen divided rays; the first spine measures 2 mm, the second spine measures 14 mm, the outline of the soft anal fin is slightly rounded, with the third ray longest, 21 mm, the last ray 11 mm.

Pectoral fins evenly rounded, with twelve divided rays and on each side two simple rays. The first simple ray (counting in the usual way from above downwards) is small, about one-third the length of the longest rays; the second simple ray is much longer, more than twice the length of the first simple ray and but very little shorter than the first divided ray.

Ventral fins long, with a fairly strong spine of 14½ mm length, and five divided rays, the second of which is the longest and measures 30 mm. When closed the fin is pointed, its tip reaching to the basis of the fifth anal ray, when spread out it has a more rounded appearance.

Caudal fin normally developed, probably with two rounded lobes as in other Apogonidae (the tip of the tail is damaged, so that one cannot be certain). There are twelve divided rays besides on each side two developed simple rays, as well as several rudimentary ones.

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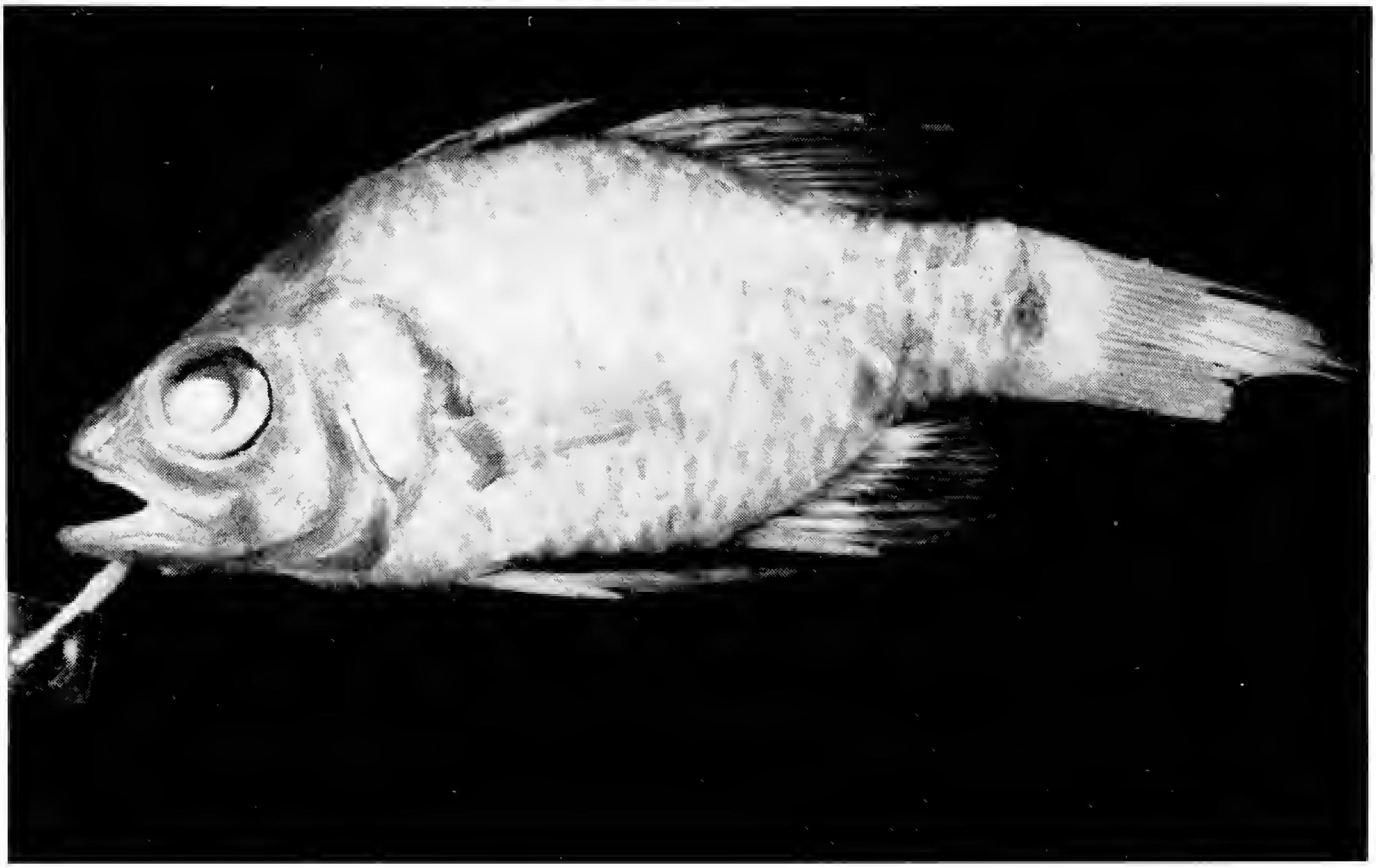

Fig. 1.—*Quinca mirifica* gen. et sp. nov.; type specimen; x 1–.3.

Colours in a preserved condition. The body is light brown; each scale has a well-defined pale (yellowish-white) hind border; the vertical fins mainly blackish, but the posterior part of D_2 is whitish near the basis, and the basal one-third of A is white; pectorals hyaline, ventrals blackish, caudal hyaline.

Type and only specimen, the individual on which the above description is based, collected at Yampi Sound, Kimberley Division, Western Australia, in August or September 1959, by Mr. G. A. Robinson, W.A.M. no. P 5787.

Distribution and habitat. The single specimen known of the species is, like all Mr. Robinson's material, merely labelled "Yampi Sound", but actually Mr. Robinson's collecting was done during low tide on the reefs of Cockatoo Island. It is evident, therefore, that *Quinca mirifica*, like other Apogonidae, is a reef-fish.

Discussion

The discovery of a species of the Apogonidae with fourteen rays in the dorsal fin is unexpected. While in many families differences in fin-ray numbers are of no more than specific value, and differ from species to species, in the Apogonidae it had become accepted that the number of rays in the dorsal fin varies only from seven to ten, and this has been included as a family-character in recent descriptions (Weber and de Beaufort, 1929; Fowler and Bean, 1930). In view of the large number of species known in the Apogonidae it is surprising to find a species which is aberrant in this one character, although in all other characters it conforms with the family, and in particular with the genus *Apogon*.

There are few instances in which I would regard a difference in number of fin-rays as enough to establish a genus on, but in the present case, for the reasons given above, I feel fully justified in doing so. Only if in future additional species might be discovered which would bridge the gap in finray-numbers between *Apogon* and *Quinca*, a reconsideration of the validity of the latter genus could become necessary.

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11.—Metamict allanite from pegmatites cutting basic charnockitic granulites in the Fraser Range, Western Australia

by Allan F. Wilson*

Manuscript received 21 September 1965; accepted 23 November 1965

Abstract

A metamict allanite from a muscovite pegmatite which cuts pyroxene granulites is chemically similar to normal allanites in most respects. However, MgO (1.96%) and Al_2O_3 (17.20%) are slightly more abundant than normal, whereas ThO_2 (0.79%) and H_2O+ (1.08%) are slightly lower. Values for U, Th and Pb indicate an age of 1210 m.y., which is thus a minimum age for the granulites of the Fraser Range. This age is similar to that determined by using Rb/Sr and K/A techniques on muscovite from the allanite-bearing pegmatite.

Small black masses of isotropic "hydroallanite" were found by a prospector near Newman Rock, east of the Fraser Range, in 1908. In 1934 another prospector from a similar area submitted to Dr. E. S. Simpson several pounds of brownish black vitreous material, which on examination was found to be an isotropic "hydroallanite".

An analysis of a "hydroallanite" from the Fraser Range is given by Simpson (1948 p. 30); see Table 1 (actually a normal allanite). The precise locality is not stated. However, the chemical analysis of the sample is very similar to the new allanite described below, and may well come from the same pegmatite.

In 1952 I collected several pounds of metamict allanite from a number of pegmatites about 300 yards south of the Eyre Highway near the 73 mile-post from Norseman. Allanite for analysis was taken from a shallow prospecting pit dug for either muscovite or allanite. Weathered fragments of allanite (up to 10 cm x 4 cm x 3 cm) have been found on the surface near adjacent pegmatites.

The areal distribution of the allanite-bearing pegmatites is shown in Figure 1. The strike of the main pegmatite is about 27°. The dip of the pegmatite was not observed as no good contacts with the country rock were found. However, from topographic considerations it is likely to be steeply dipping.

The country rocks are dominantly basic granulites of charnockitic type, which are cut by metagabbro dykes (Wilson 1965). The regional trend of the granulites is shown in Figure 1.

The dominant mineral aggregate is a very handsome coarse microcline-quartz graphic intergrowth which is commonly 30 cm in diameter and up to 2 metres in diameter. Quartz, which tends to form an ill-defined core is commonly a dark smoky variety, especially in the vicinity of the pit where allanite occurs. Muscovite, which looks dark in hand specimen, and biotite occur patchily throughout most of the pegmatites. Black tourmaline and magnetite are other important accessory minerals. A geiger counter was used (without success) to try to locate hidden pockets of allanite or other radioactive minerals. Zoning in the pegmatite was not studied in detail.

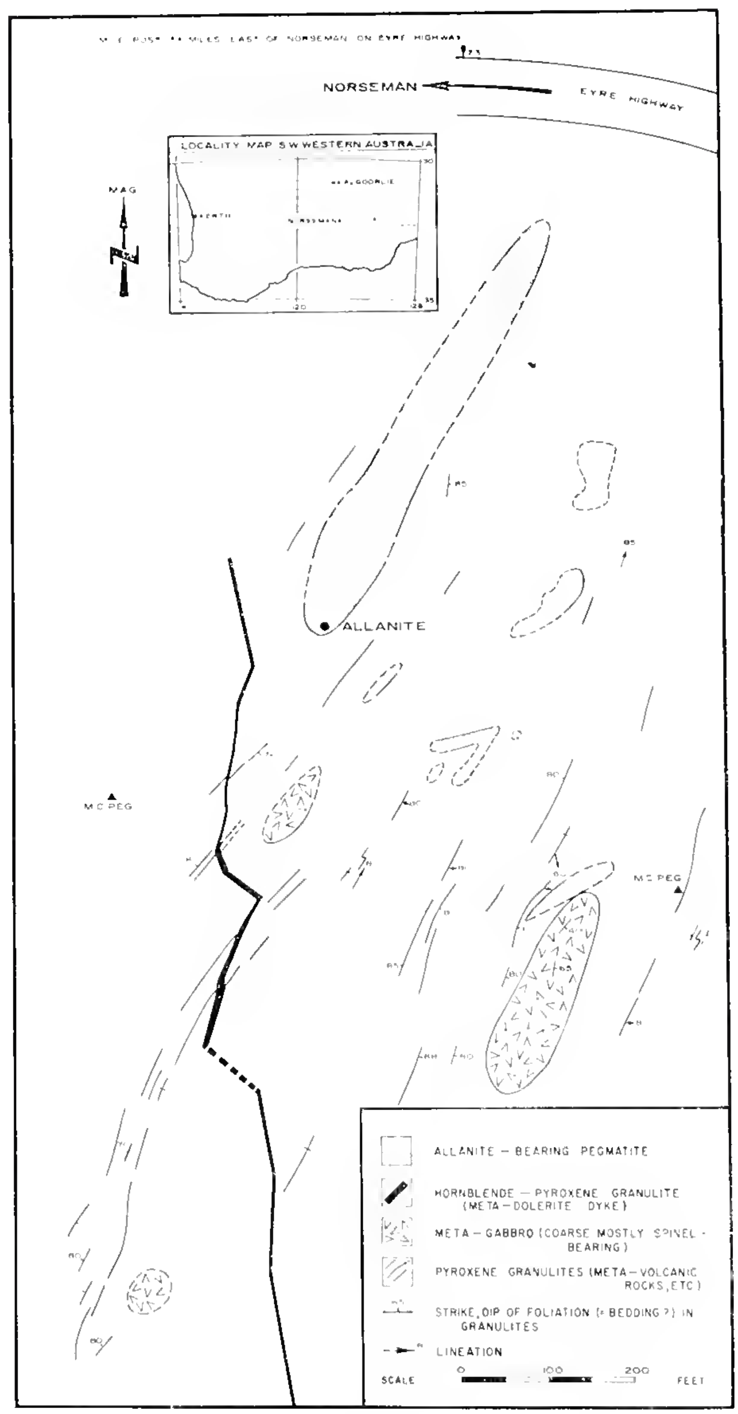

Fig. 1.

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A carefully handpicked sample of allanite was submitted to the Government Chemical Laboratories, Perth. Mr. J. N. A. Grace made a chemical analysis of the mineral. In addition, U, Th and Pb were determined on another portion of the original crystal. These results were originally required (in 1953) for an estimation of the age of the allanite.

Analyses of this allanite and of the other metamict allanite from the Fraser Range are set out in Table 1. The mean atomic weight of [La] was taken as 144, and of [Y] as 120 (following Hasegawa 1960 p. 352).

Hasegawa has shown from his exhaustive study (1960 p. 374) that allanite is a variety of epidote, $Ca_2(Fe^3Al)_3Si_3O_{12}(OH)$, in which a part of the Ca is replaced by rare earth atoms, and a part of Fe^3 or Al atoms by Fe^2. He points out that the replacement does not take place completely but is confined within narrow limits. Hasewaga gives the general formula and limits of composition, thus:—

$(Ca_{2-n}Ce_n)_2\ (Fe^2{}_nFe^3{}_{1-n})\ (Fe^3{}_mAl_{2-m})_2\ Si_3O_{12}(OH)$ where $1.00 > n > 0.60$, $0.45 > m > 0.05$, Ca = Ca + Mn, Ce = total rare earths and Th, Fe^2 = Fe^2 + Mg, and Al = Al + Be + Ti.

The chemical characteristics of the two allanites from the Fraser Range are very similar, and fall within the range of common allanites in most respects. However, MgO and Al_2O_3 are slightly more abundant than normal, whereas ThO_2 and H_2O+ are slightly low.

In 1952 an attempt was made to determine the age of the Fraser Range pegmatites. Allanite was first analysed for the normal constituents, and from a larger sample U, Th and Pb were determined. Moreover, an unsuccessful attempt was made to extract enough Pb for isotope analysis. From the normal analysis ThO_2 was given as 0.79 (i.e. Th = 0.69) whereas the data from the large sample was U = 0.06, Th = 0.87, Pb = 0.064.

TABLE 1

Allanite, 10 miles east of Fraser Range Homestead, Fraser Range, W.A.

Analyst: J. N. A. Grace 1953 (Gov. Chem. Lab. No. 6126/52).

Weight %		Atomic Proportions X10000		Atomic Ratios	
CaO	11.46	Ca	2044	1.12	
MnO	0.46	Mn	65	0.04	
ThO_2	0.79	Th	30	0.02	1.87
Ce_2O_3 / $[La]_2O_3$	20.67	[Ce]	1245	0.68	
$[Y]_2O_3$	0.17	Y	12	0.01	
FeO	8.44	Fe^{+2}	1175	0.64	
MgO	1.96	Mg	486	0.27	1.25
Fe_2O_3	4.93	Fe^{+3}	617	0.34	
Al_2O_3	17.20	Al	3374	1.84	2.27
TiO_2	0.63	Ti	79	0.43	
SiO_2	32.21	Si	5360	2.93	2.93
H_2O+	1.08	OH	1200	0.66	0.66
H_2O-	0.02	O	21979	12.00	12.00
	100.02				

n = 1.681 ± 0.001 ; S.G. = 3.40.

Formula (on the basis of twelve O) :

$(Ca_{1.12}Mn_{0.01}\ [Ce]_{0.68}\ [Y]_{0.01}\ Th_{0.02})_{1.87}\ (Fe^{+2}{}_{0.64}\ Mg_{0.27}\ Fe^{+3}{}_{0.34})_{1.25}\ (Al_{1.84}\ Ti_{0.43})_{2.27}\ Si_{2.93}\ O_{12.00}\ OH_{0.66}$

Using the values of U, Th and Pb an age of about 1210 x 10^6 years may be calculated. This compares remarkably favourably with the Rb/Sr and K/A ages (1280 x 10^6 and 1210 x 10^6, respectively) measured by Dr. W. Compston on muscovite (No. 41295) from the same pegmatite (Wilson *et al.* 1960. Table 1. No. 22).

The significance of the age of the allanite-bearing pegmatite is that it gives the minimum age of the charnockitic rocks of the Fraser Range. It is likely that the pegmatite was emplaced at the end of the grand phase of metamorphism which converted the country rocks to granulite facies. Thus the peak of the metamorphism is considered to be close in time to 1210 x 10^6 years ago. The structure and age relationship of the Fraser Range to the rest of the Shield may be seen from the map and text of earlier publications (Wilson 1958, pp.77, 80 etc.; Wilson *et al.* 1960 p.186; Wilson 1965).

TABLE 2

Allanite, Fraser Range, W.A. (Simpson 1948 p.30)

Weight %		Atomic Proportions X10000		Atomic Ratios	
CaO	11.91	Ca	2124	1.17	
Na_2O	0.01	Na	3	0.00	
K_2O	0.08	K	18	0.01	
MnO	0.55	Mn	78	0.04	
ThO_2	1.04	Th	39	0.02	1.89
Ce_2O_3	9.64	Ce	588	0.32	
$[La]_2O_3$	9.20	La	548	0.30	
$[Y]_2O_3$	0.45	Y	31	0.02	
Er_2O_3	0.19	Er	10	0.01	
FeO	8.26	Fe^{+2}	1150	0.63	
MgO	1.36	Mg	337	0.19	1.21
Fe_2O_3	5.73	Fe^{+3}	718	0.39	
Al_2O_3	17.48	Al	3429	1.88	1.90
TiO_2	0.24	Ti	30	0.02	
SiO_2	32.69	Si	5440	2.99	2.99
P_2O_5	0.02	P	3	0.00	
H_2O+	1.55	OH	1722	0.95	0.95
H_2O-	0.15	O	21834	12.00	12.00
	100.65				

n = 1.690 : S.G. = 3.34

Formula (on the basis of twelve O) :

$(Ca_{1.17}\ K_{0.01}\ Mn_{0.01}\ Ce_{0.32}\ [La]_{0.30}\ (Y)_{0.02}\ Er_{0.01}\ Th_{0.02})_{1.89}\ (Fe^{+2}{}_{0.63}\ Mg_{0.19}\ Fe^{+3}{}_{0.39})_{1.21}\ (Al_{1.88}\ Ti_{0.02})_{1.90}\ Si_{2.99}\ O_{12.00}\ OH_{0.95}$

TABLE 3

Comparison of chemical composition of the two Fraser Range allanites and the general range of chemical variations of 126 allanites from elsewhcre in the world (after Hasegawa, 1960).

	1 Wt. %	2 Wt. %	General range of world allanites (extremes excluded) Wt. %
CaO	11.46	11.91	6–13
MnO	0.46	0.55	0–7 (mostly 0–2)
ThO_2 . .	0.79	1.04	Close to 1
Rare earths ..	20.84	19.48	19–27
FeO	8.44	8.26	5–14 (mostly 9–13)
MgO	1.96	1.36	0–1
Fe_2O_3 ...	4.93	5.73	2–10
Al_2O_3	17.20	17.48	14–17
TiO_2	0.63	0.24	0–1
SiO_2 .. .	32.21	32.69	30–34
P_2O_5	n.d.	0.02	< 1
H_2O+	1.08	1.55	1.5–2

1 = Allanite, 10 miles east of Fraser Range Homestead.
2 = Allanite, Fraser Range (Simpson 1948 p. 30).

Acknowledgements

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12.—A fossil bone deposit near Perth, Western Australia, interpreted as a carnivore's den after feeding tests on living Sarcophilus (Marsupialia, Dasyuridae).

by A. M. Douglas,* G. W. Kendrick* and D. Merrilees*

Manuscript received 15 February 1966; accepted 15 March 1966

Abstract

Carcases of marsupials have been fed to living specimens of the Tasmanian Devil (*Sarcophilus harrisi*), and the bony content of these carcases has been recovered. The kinds of damage inflicted by *Sarcophilus* on bone have been compared with damaged bone from an old cave deposit near Wanneroo, in the vicinity of Perth, Western Australia. This deposit contains remains of *Sarcophilus*, and it is concluded that the deposit represents the den or feeding place of *Sarcophilus*, probably of late Quaternary age.

Introduction

In 1964 we found a bone-bearing deposit in abandoned limestone quarries near Wanneroo, north of Perth, and in 1965 collected systematically from this deposit. Most of the bone in the deposit was in the form of small fragments, but among the larger identifiable fragments were some attributable to *Sarcophilus*. *Sarcophilus* still survives in Tasmania, where it is known as the "devil"; it is carnivorous. The association of fragmented bones with identifiable *Sarcophilus* remains suggested that our Wanneroo deposit represented a den or feeding place of *Sarcophilus*, and this suggestion received support from the feeding tests on living *Sarcophilus* specimens and from the other observations reported below.

Feeding tests on living Sarcophilus

Two young specimens of *Sarcophilus*, a male and a female, were obtained from Tasmania in 1965 by the Western Australian Museum. By kind permission of Mr. J. A. W. Kirsch, one of us (A.M.D.) was able to feed these animals with selected carcases under controlled conditions and study the resulting bony rejectamenta.

The feeding tests were conducted in June and July 1965. The animals were fed meat containing no bone (e.g. bullock hearts) for 3 days and then presented with 2 intact carcases of *Trichosurus vulpecula* (the brush-tailed possum) which had been freshly trapped and killed. These carcases were eaten over a period of 3 days, after which all faeces and unconsumed portions of the carcases were collected. The *Sarcophilus* specimens were then presented with 2 further *Trichosurus* carcases, which were left in the cage for 2 days. The cage was then cleaned out thoroughly, the animals were fed meat containing no bone, and their faeces were examined until it was clear (after 3 days) that no *Trichosurus* bone or fur remained in their intestines.

* Western Australian Museum, Perth, Western Australia.

They were then presented with the carcases of 2 short-nosed bandicoots (*Isoodon obesulus*); these were largely ignored, and very little had been eaten after 4 days, one remaining quite intact. Unconsumed carcase material was collected, and the "devils" were placed on a bone-free diet until they ceased to pass bone or fur (after 2 days.) They were then presented with part of a carcase of a western grey kangaroo (*Macropus giganteus*—for nomenclature see Ride 1963) from which the skin, one fore-leg, one hind-leg and much of the remaining flesh had been removed. Only the uneaten bony material, not the faeces, was collected in this case also.

Observations on the feeding habits of these two *Sarcophilus* specimens, together with details of experimental procedures with the animals and with their bony rejectamenta have been recorded in a report by A. M. Douglas which has been lodged in the library of the Western Australian Museum.

Some of the *Sarcophilus* faeces containing *Trichosurus* fur and bone were treated with chlorocresol, dried in an oven, and preserved intact (W.A.M. specimen 65.11.1). The very fine bone fragments (65.11.3) were isolated from all the remaining faeces which were recovered. Some of the faeces so treated, consisting mainly of matted fur but still containing larger fragments of bone, were dried and have been preserved (65.11.2). The remaining faeces were hand-picked to remove the larger fragments of bone, and this bony material (65.11.4) was retained.

The uneaten *Trichosurus* fragments were cleaned of all flesh with the exception of one fore-leg (65.11.5) from one of the first pair of *Trichosurus* carcases. The cleaned bony rejectamenta from the first 2 *Trichosurus* carcases have been catalogued as 65.11.6 and 65.11.7; the rejectamenta from the second 2 *Trichosurus* carcases, also cleaned, have been catalogued as 65.11.8 and 65.11.9. The uneaten portions of the one *Isoodon* carcase which was attacked have been cleaned and retained as specimen 65.11.10. The uneaten portions of the partial *Macropus* carcase have been cleaned and retained as 65.11.11.

The specimens quoted above resulting from these feeding tests on living *Sarcophilus* have been compared with the fossil material from Wanneroo.

The Wanneroo Sarcophilus den

The suspected *Sarcophilus* den is in Dunstan's Lime Kiln Quarries, an extensive series of quarries, now abandoned, about 9 miles north of the township of Wanneroo, and about 24 miles north of the central city area of Perth, Western Australia. These quarries cut into the extensive rock formation informally known as the "Coastal Limestone". One of the quarry roads runs alongside a low quarry face partly composed of a coarse calcareous breccia which we interpret as an old cave fill or floor deposit. The mass of breccia exposed above the roadway is about 60 feet long, and rises from road level in the west to a height of about 10 feet in the east; several parts of the mass contain bone fragments. The breccia carries a capping of calcareous aeolian dune rock typical of the "Coastal Limestone". We interpret this capping as the remnant of a cave roof which formerly was more extensive, but which has been reduced by natural processes to a thickness of only a few feet. The whole mass is surmounted by a soil carrying a plant cover. Quarrying or road-making operations have produced a vertical section of depth about 12 feet in this composite system of soil, aeolianite and breccia.

About central in the vertical section is a cavity with opening about 9 feet wide and about 3 feet high, penetrating about 10 feet into the rock mass. This cavity appears to be the remnant of a formerly more extensive cave which had been partly filled by a tumbled mass of rock fragments and more finely divided material now represented by the breccia. The lower parts of the cavity as it now exists are defined by bone-bearing breccia, the roof by dune rock.

The breccia so far described is a well cemented and coherent rock, and its bone content is fragile, so that it is difficult to recover identifiable specimens from it. However, there is an unconsolidated deposit in the floor of the cavity, and this unconsolidated deposit is rich in bone fragments which are easily recoverable by sieving. We have examined a little fossil material from the consolidated breccia, and a larger

Figure 1.—Comparison of damage inflicted by living *Sarcophilus* on modern bone with damaged bone from Wanneroo fossil deposit. In each group or pair of specimens (a-i) the fossil bone is darker than the modern, and the fossil specimen or specimens are placed immediately below their modern counterparts. a.—bone chips of generally similar size; b.—roughly circular punctures; c.—mandibular rami complete in front, but with rear ends irregularly fractured; d and e.—irregular embayments part way along bones; f and h.—similarly fractured ends in bones of similar size; g.—fractures incompletely separating chips from shafts of bones; i.—fractures in bones of such size that carnivores smaller than *Sarcophilus* can hardly have been responsible.

quantity obtained by systematic sieving of portion of the unconsolidated floor deposit. It is probable that this unconsolidated deposit contains bone specimens derived from the consolidated breccia by weathering, and it may contain bone of more recent origin.

The consolidated breccia has yielded fragments of *Sarcophilus* (65.10.194), of *Petrogale* (65.10.201, 65.10.202?) and of other phalangercids, not specifically identifiable but of medium size (65.10.203-205). The unconsolidated floor deposit has yielded *Sarcophilus* (65.10.191-193, 65.10.195), *Dasyurus* (65.10.174-176), *Petrogale* (65.10.162-170, 65.10.188-190, 65.10.196-197), *Bettongia penicillata* (65.10.177), *Bettongia lesueuri* (65.10.178-187), some other macropods of medium size (65.10.198-199), a large macropod (65.10.172, 64.1.10), *Isoodon* (65.10.161) and a murid (64.1.11). Of these mammals the rock wallabies (*Petrogale* sp.) and the rat kangaroos (*Bettongia lesueuri*) are most abundant. Among the non-mammalian fossils in the unconsolidated floor deposit we have recognized *Varanus* (65.10.159) and other lizards (65.10.160), the snails *Bothriembryon* (65.1168), *Luinodiscus* (65.1177) and *Austrosuccinea* (*sensu* Iredale) (64.1) and the mussel *Westralunio* (64.2). Presumably the mussel was transported by some scavenging or predatory animal, perhaps by man.

Comparison of modern with Wanneroo bone samples, and discussion

We have not attempted to estimate proportions of bone fragments of given size ranges in the modern and fossil samples because we believe the conditions under which the samples were produced probably were different. Under natural conditions, *Sarcophilus* might drag smaller carcases back into a den to feed upon, whereas it might attack large carcases only in the field. In a den, *Sarcophilus* might be expected to chew carcases thoroughly, whereas uneaten portions of carcases were removed from our modern caged animals every few days. Possibly, an animal under natural conditions might avoid defaecating in its den, so that the den deposit would come to contain only a small portion of the most finely divided bone.

Our comparisons therefore have included only rough estimates of relative proportions of bone fragments of different sizes in our two samples, and have centred upon the nature of fractures, punctures and incisions in the samples. Close similarities between the two samples are observable; see Figure 1. In this Figure the specimens have been arranged in pairs, with a piece (or pieces) of bone attacked by the modern animals above in each pair, and a (darker) piece from the Wanneroo deposit below. In each pair of specimens, the kind of damage visible on the modern specimen appears to be similar to that on the fossil specimen. We have noted no kind of damage in the modern sample which cannot be matched from the fossil sample, and vice versa.

It is to be expected in a cave deposit that some of the bony content would have been crushed or broken by blocks of rock falling from the roof, and it might not always be possible to decide whether a given fracture in a piece of bone resulted from tooth action or falling rock. However, certain kinds of damage, such as more or less circular punctures or rather frayed embayments part way along pieces of bone, appear to be much more readily explained as tooth action than as falling rock action.

Sarcophilus is not the only carnivore which could be envisaged as accumulating the bones found at Wanneroo; *Thylacoleo, Thylacinus,* or *Canis* might be involved. Smaller carnivores such as *Macroderma*, owls, *Phascogale* or even *Dasyurus* might be expected to accumulate a far greater proportion of small mammal and other small vertebrate prey. Lizards, rodents and other small animals are poorly represented in the Wanneroo deposit, rock wallabies and rat kangaroos predominating. Thus, although the deposit contains the remains of *Dasyurus* as well as of *Sarcophilus,* the latter is more likely to have accumulated most of the bone in the deposit.

Marks on Australian fossil bones have been interpreted as damage inflicted by the teeth of carnivores by several writers, notably by Spencer and Walcott (1912) in their discussion of the food habits of *Thylacoleo*. But it has not been suggested that any particular kind of damage indicates any particular carnivorous species, and we have noticed no kind of damage that might reasonably denote *Sarcophilus* rather than any other carnivore. *Sarcophilus* is the only one of the larger carnivores so far recognized in the Wanneroo deposit. Thus it is reasonable to postulate that *Sarcophilus* may have been responsible for most of the bony content of the deposit. Accumulations of bone in Western Australian localities have been ascribed by Lundelius (1960 and 1963) to *Sarcophilus* because of the association of much-fragmented bones of medium-sized animals with *Sarcophilus* remains in the same deposit.

The "Coastal Limestone" enclosing the Wanneroo deposit is of Quaternary age (Smith 1963). Consequently the deposit itself is probably of late Quaternary age, but we are not at present able to estimate this age more precisely.

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We wish to thank Dr. R. W. George for critical discussion of this work, and Mr. W. B. Sewell for the photograph reproduced.

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Royal Society Medallist 1966

C. F. H. Jenkins

Clee Francis Howard Jenkins, the tenth recipient of the Society's Medal awarded for distinguished work in science connected with Western Australia, was born in Adelaide in 1908. He received his education at St. Peter's College, Adelaide, and graduated as Bachelor of Arts in the School of Science of the University of Western Australia in 1935. In 1939 he received his Master's degree. After joining the staff of the Western Australian Museum as a cadet in 1929 he was appointed to the Western Australian Department of Agriculture as an entomologist in 1933, and as Government Entomologist in 1939. In 1964 he was appointed Chief of the Department's Division of Biological Services, incorporating Entomology, Botany, Plant Pathology and Weeds and Seeds, a position which he continues to hold.

Mr. Jenkins receives the Society's Medal jointly for his exceptional service to the Society, a primary purpose of which is the advancement of science in all its branches, and for his personal achievements in his own field.

He first joined the Society in 1929 and began active work for it with his election as Assistant Librarian. Since then he has served in Executive or Council positions for 31 years as follows—Hon. Secretary for 10 years, Vice-President for 4 years, President for 2 years, and a Member of Council for 15 years, in which position his service continues. His two terms in the Presidential chair were separated by 18 years. In addition he has been a member of a number of Council Committees, including Chairman of the important Standing Committee on Conservation.

His work with the Department of Agriculture has been mainly in the field of insect control, for which he has been responsible since 1939. The importance of such studies to the agricultural industry of the State can hardly be overemphasized.

His early work on grasshopper control contributed to the present low incidence of this pest. Later he advised on the control of insect pests at military camps and carried out a survey of insects that bite rabbits, for the spreading of myxomatosis. His sound recommendations for eradication are responsible for the absence from Western Australia of such important pests as codling moth, oriental fruit moth, and sirex wasp, as well as for the reduction of fruit fly to its present low level. Probably the best known of his projects is that of argentine ant control, the cost of which has reached approximately $1,500,000 and which has involved the treatment of 40,000 acres of infestation. At the Department of Agriculture he has maintained and increased a collection of insects which now number about 100,000, including many type specimens.

Mr. Jenkins has also made a distinguished contribution to science by his enthusiastic encouragement of natural history, and in particular ornithology. He has been closely associated with the Australasian Ornithologists' Union, the Western Australian Naturalists' Club, the Western Australian Aviculture Society and the Western Australian Gould League. In 1963 his advice was sought when H.R.H. The Duke of Edinburgh expressed a preference for bird-watching to the more conventional occupations of royal visitors. He maintained a weekly newspaper column on natural history for many years, and still continues the similar radio talks he has made for the last 15 years, in addition to frequent other broadcast and television presentations. His ability has been recognised by deputy presidency of both the National Parks Board of Western Australia and the Zoological Gardens Board. He is also a Council member of the National Trust, the newly formed Australian Conservation Foundation, and Vice-Chairman of the Western Australian Division of A.N.Z.A.A.S.

Erratum

A new species of Nectria (Asteroidea, Goniasteridae) from Western Australia, by S. A. Shepherd and E. P. Hodgkin; Volume 48, Part 4, Paper 11 of the Journal.

Mr. Shepherd's name was misspelt "Sheperd" in the published Journal. The error was corrected in the reprints, with a footnote drawing attention to the change.

INSTRUCTIONS TO AUTHORS

Contributions to this Journal should be sent to *The Honorary Secretary, Royal Society of Western Australia, Western Australian Museum, Perth.* Papers are received only from, or by communication through, Members of the Society. The Council decides whether any contribution will be accepted for publication. All papers accepted must be read either in full or in abstract or be tabled at an ordinary meeting before publication.

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Typescripts should be double-spaced on opaque white foolscap paper; the original and one carbon copy should be sent. All Tables, and captions for Figures, should be on separate sheets. To avoid unnecessary handling of the original illustrations authors are requested to include additional prints, preferably reduced to the final size required; a choice of either one-column (about 2.8 inches) or two-column (about 5.8 inches) width is available. The preferred positions of Figures should be marked on the second typescript copy.

In the preparation of references, and for all matters of presentation not otherwise covered in these instructions, authors are required to follow the C.S.I.R.O. *Guide to Authors* (Melbourne, 1963). Failure to read through this carefully before preparing papers may lead to delay in publication. The use of the various conventional systems of nomenclature recommended in this booklet, and in the supplementary pamphlets referred to in it, is obligatory; for this purpose, palaeontological papers must follow the appropriate recommendations for zoology or botany. All new stratigraphic names must have been previously approved by the Stratigraphic Nomenclature Committee of the Geological Society of Australia.

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13.—The genus Hednota Meyrick (Lepidoptera; Pyralidae, Crambinae) in the south-west of Western Australia, with particular reference to economic webworm species

by L. E. Koch*

Manuscript received 22 June, 1965; accepted 17 August, 1965

Abstract

Four species of *Hednota* are recognized as pests causing severe damage to crops of wheat, barley and rye, and introduced pasture grasses in Western Australia. The larvae of these species, *H. panteucha* (Meyrick), *H. longipalpella* (Meyrick), *H. pedionoma* (Meyrick), *H. crypsichroa* Lower, are collectively known as webworm and cause the damage by eating the young plants during winter.

Sixteen additional species of *Hednota* are known from the south-west of Western Australia. The taxonomy of all the adults, and of the immature stages of the four economically important species is presented.

Included are designations of lectotypes of Meyrick's species, *Eromene longipalpella*, *Thinasotia pedionoma* and *Crambus hoplitellus*, and Lower's *Hednota crypsichroa* and Walker's *Crambus relatalis*, together with the descriptions of five new species, *H. ancylosticha*, *H. koojanensis*, *H. tenuilineata*, *H. odontoides* and *H. empheres*.

Introduction

The term "webworm" has been previously used in Western Australia for larvae referred to as many as six species in five genera in the family Pyralidae (Lepidoptera). These larvae gained their common name from their habit of using silken webbing to line their burrows in the soil and to construct tubes among their food-plants. They make large bare patches among certain cereal crops and introduced-grass pastures (Fig. 1) by feeding on the fresh blades of the young plants from late autumn until early spring.

Webworm was first recorded as a pest by Newman (1921). Since then, in Western Australia, these larvae have reached the stage where they rank with the most important economic insects, having become the most serious insect pest of cereal crops. In recent years, e.g. 1962, severe damage has also occurred in South Australia.

Greatest concern has been aroused by the damage to wheat, *Triticum aestivum* L., but crops of barley, *Hordeum vulgare* L., and rye, *Secale cereale* L., have also been attacked. Crops of oats, *Avena sativa* L., have been left undamaged. Of the introduced grasses, barley grass, *Hordeum* spp., has been the favourite host; and silver grass, *Vulpia* spp., and brome grass, *Bromus* spp., have been included in the diet (Wallace and Mahon 1952).

Four species of the pyralid subfamily Crambinae have now been positively associated with the damage. Bleszynski and Collins (1962) have catalogued these species within two genera, *Surattha* and *Hednota*. In the present paper, I refer all four species to *Hednota*. Members of *Hednota* occur mainly in Australia, and most of them are found in the more temperate portions of the continent.

The term "webworm" is well established throughout the farming community of Western Australian and therefore needs clear definition. I recommend its restriction to the Crambinae which cause the economic damage; and I here use the term collectively for the four *Hednota* species.

The results of the present taxonomic paper were obtained during concurrent investigations by me into the biology and ecology of webworm in Western Australia. (Details of my findings on biology and ecology have not yet been published.) I began this project on webworm in 1960 at the Western Australian Department of Agriculture and continued it at the University of Western Australia and the Western Australian Museum.

A brief outline of the seasonal cycle of webworm in the south-west of Western Australia is as follows. Only one generation is completed each year. The moths fly and lay eggs in autumn, mostly in April. The larvae feed from within individual vertical tubes and burrows. Between August and early October the final instar larvae deepen their burrows in the soil and remain in them until about March the next year. Then they pupate within the burrows; and, a few weeks later, the moths emerge.

One of the species, *H. panteucha* (Meyrick), was found to be the predominant species over a large part of the area of webworm distribution in Western Australia, and the biological and ecological studies were performed mainly on this species.

* Western Australian Museum, Perth.

This paper deals with the adults of the species of *Hednota* found in the south-west of Western Australia, and includes findings on the immature stages of the four webworm species. Following a request by Mr. P. E. S. Whalley, I herein designate lectotypes for four of the species represented by syntypes, which were only at the British Museum (Natural History). And I designate one lectotype in the South Australian Museum. During the investigation, five new species were discovered in Western Australia, and I describe them in this paper. (As far as I know, only one of these new species occurs outside Western Australia.)

The identity of webworm has gradually emerged since Newman (1921) first recognized the pest; and because there has been no complete review of the literature and the nomenclatural history of webworm, I find it necessary to present such a treatment in this paper before proceeding to the taxonomy of the adults of *Hednota*.

Figure 1.—Severe damage (dark areas on the ground) by webworm to pasture at Katanning, W.A., in 1949.

Materials and methods

I collected webworm adults from a light trap set at Koojan (near Moora), and the C.S.I.R.O. has provided me with the Crambinae collected in light traps at Nedlands (in Perth) and Glen Lossie Field Station at Kojonup.

I have examined the relevant adult specimens sent to me from all Australian institutions (except those in Tasmania) known to have Crambinae. Examined specimens of the four webworm species collected from all parts of Australia are listed. These lists are long and summaries are provided to assist the reader readily to see the distribution. In these summaries of distribution are included the additional localities, from the literature and from the label data of British Museum (Natural History) specimens, which are given by me in more detail under comments. Of the other *Hednota* species which occur in the south-west of Western Australia, only specimens caught there are listed.

Label data of the specimens examined are given in abbreviated form for each species. The following abbreviations are used:—

Collections: Australian National Insect Collection, Canberra, ANIC; Queensland Museum, QM; Australian Museum, New South Wales, AM; National Museum of Victoria, NM; South Australian Museum, SAM; Western Australian Museum, WAM; Queensland Department of Agriculture and Stock, QDAS; Victorian Department of Agriculture, VDA; South Australian Department of Agriculture, SADA; Western Australian Department of Agriculture, WADA; Waite Agricultural Research Institute, South Australia, SAW; C.S.I.R.O. Western Australian Regional Laboratory, WAC.

Collectors: W. B. Barnard, WBB; J. D. Beresford, JDB; G. F. Berthoud, GFB; R. W. Bolt, RWB; J. A. Button, JAB; I. F. B. Common, IFBC; A. M. Douglas, AMD; P. N. Forte, PNF; C. F. H. Jenkins, CFHJ; L. Jenkins, LJ; L. E. Koch, LEK; P. J. Lawrence, PJL; J. A. Mahon, JAM; G. S. McCutcheon, GSMC; L. J. Newman, LJN; R. J. Priest, RJP; A. L. Rogers, ALR; D. G. Shedley, DGS; A. Sproul, AS; M. S. Upton, MSU; M. M. H. Wallace, MMHW.

Material collected prior to 1961 was lodged in the insect collection of the Department of Agriculture of Western Australia. Since then all my material (consisting of thousands of adults from all the mentioned light traps, the immature stages and the microscope slides which were prepared) has been lodged in the Western Australian Museum. Only a representative sample of the pinned material from this Museum is listed with the examined specimens.

I have unfortunately been unable to examine type specimens in the British Museum (Natural History). But I have obtained, in personal communications from Mr. P. E. S. Whalley, and include in this paper the following kinds of information on relevant specimens, which have been sorted by Dr. S. Bleszynski, in that institution: a list of specimens ("label data exactly as written") of the four webworm species; label data of type specimens; and comments on the comparison (by Whalley) of my microscope slides of genitalia of some of the species with genitalia slides of some of their specimens.

I include in this paper, drawings and descriptions of the genitalia of the four webworm species (this will enable the identification even of badly rubbed specimens of economic importance). And because of the close similarity of *H. ancylosticha*, sp. nov., *H. koojanensis*, sp. nov., and *H. empheres*, sp. nov., to *H. longipalpella* (Meyrick), *H. peripeuces* (Turner) and *H. relatalis* (Walker) respectively, I also here treat the genitalia of these. (At this stage I am unable to publish a taxonomic treatment at the generic level of all the species listed in the genus *Hednota* by Bleszynski and Collins (1962)).

The diagnostic drawings were made freehand on squared paper while viewing through a squared graticule in the microscope. The uncus and gnathos of the male genitalia are shown in both ventral and lateral views to assist identification.

Unlike the plain antennae of the females, antennae of the males are pectinate or bipectinate; and characters of male antennae are included in the diagnoses where helpful.

The markings on the forewings serve as outstanding characters for identification, and they are detailed in the diagnosis of each species.

Discussion of the literature and the nomenclatural history of webworm

Newman (1921) incorrectly attributed webworm damage to one species of *Crambus* (Crambinae). Then he (Newman 1927) misidentified webworm as *Sclerobia tritalis* (Walker) (Phycitinae); and in this general paper, he confused the damage caused by webworm and *Sclerobia tritalis* (misspelling it as *tritialis*). He combined some observations on the biology of *S. tritalis* with those on webworm. His illustrations were of *S. tritalis*. [This species was described as *Hypochalcia tritalis* by Walker (1863). Turner (1904) regarded *Eucarphia vulgatella* Meyrick, 1879, as a synonym of *Hypochalcia* which he misspelled *Hypochalchia)* *tritalis* and placed them both in the genus *Sclerobia* as *S. tritalis*.] Later, Newman (1932) further discussed webworm damage, but still called the species responsible *S. tritalis* [sic] and again illustrated this species.

Wallace and Mahon (1952) discussed damage by webworm, which they tentatively called the pasture webworm, *Talis pedionoma* (Crambinae). Following the example of the above papers, Gay (1955) in a list of common names, called *S. tritalis* the webworm and *T. pedionoma* the pasture webworm. Jenkins and Forte (1952) and Jenkins (1958) said that either more than one species of insect is covered by the term "webworm" or the true webworm is "*Talis pedionoma* Mayr." [*sic*]. Turner (1904) had stated that the Crambinae are probably the best known subfamily of the Australian Pyralidae, and that this region is remarkable for the very few species of the large cosmopolitan genus *Crambus* and for the large development of *Talis* which appears to take its place. Over forty Australian species were included by Turner in *Talis*, of which he regarded *Hednota* as a synonym.

In Western Australia during 1949 and 1950, moths attracted in numbers to lights during autumn, in areas damaged by webworm in the previous winter, were found to be predominantly *Hednota* spp. At that time, these were regarded as *Talis* spp. according to the generic classification of Turner (1904). And insect light traps set from 1951 yielded large numbers of four species identified as *Talis panteucha* (Meyrick, 1885), *T. longipalpella* (Meyrick, 1879), *T. pedionoma* (Meyrick, 1885), and *T. crypsichroa* Lower, 1893 by Mr. I. F. B. Common, Division of Entomology, C.S.I.R.O., Canberra, on the basis of material collected chiefly at Goomalling and Toodyay and sent to him by the Department of Agriculture of Western Australia in 1951. This was the first record of *panteucha* from Western Australia; the other three species had been taken previously in the State. From 1959, I have bred adults of these four species from larvae taken from various infested places at Moora and other localities. These are the only four species in the genus which have so far been bred from larvae found among the introduced grasses and cereal crops. At the same time, light trapping has been increased and catches among the cereal crops and introduced grass pastures have contained small numbers of a few additional species of Crambinae; but there is no evidence as yet of any of these causing economic damage.

Newman's general observations apply to the above four species and not to a *Crambus* species or to *S. tritalis*. The larvae of *S. tritalis* also make silken tunnels and may be superficially confused with the larvae of the Crambinae; but they move rapidly compared to the Crambinae, and pupate at the somewhat thickened closed ends of their tunnels whereas the burrow linings of the Crambinae are of uniform thickness. Unlike these Crambinae, *S. tritalis* is multivoltine in the south-west of Western Australia. Although adults of *S. tritalis* are occasionally present with the Crambinae, I have found the larvae mainly among couch grass, *Cynodon dactylon* (L.) Pers., on which they feed.

Most of the webworm investigations in the decade before 1960 were directed mainly at determining control measures (Anon 1951; Wallace and Mahon 1952; Jenkins and Forte 1952; Anon 1953; Jenkins 1958, 1960). But some of these papers have included a broad outline of the life cycle, the most detailed account being that by Wallace and Mahon. During this period I completed a thesis which included findings on the systematics and biology of webworm (Koch 1959).

Since 1960 the Department of Agriculture of Western Australia has carried out further webworm investigations (Button 1962), and still further work by Button has recently been published (Button 1963*a*, 1963*b*, 1963*c*, 1963*d*). These investigations were planned "so that more effective and more economical methods of control can be developed." The generic name *Talis* was retained for webworm. Unfortunately, Button did not distinguish between the life cycle stages of the four species, and as his results pertain to a mixed species population they are mostly of limited value.

Wallace and Mahon (1963) have discussed some important aspects of insecticidal treatment against webworm (*Talis* spp.) and other pasture pests.

As stated, Turner considered *Talis* and *Hednota* to be subjectively synonymous. Subsequently, Bleszynski and Collins (1962) have revived the concept of an independent *Hednota*, and list in *Hednota* forty-nine species including most of the Australian species formerly placed by Turner in *Talis*. They have allocated the four *Talis* species as follows: *Surattha panteucha*, *Hednota longipalpella*, *H. pedionoma* and *H. crypsichroa*. According to them *Talis* does not occur in Australia.

I do not agree with the placement of *panteucha* in *Surattha*. Bleszynski (personal communication) agrees with this view because of the close similarity of *panteucha* to many of the species listed in *Hednota* by Bleszynski and Collins (1962); therefore I place it in *Hednota*. All the previously known species treated in *Hednota* in this paper were included in this genus by Bleszynski and Collins (1962).

Taxonomy

Pyralidae are small to medium-sized moths, usually with long legs, strong proboscis, labial palpi usually porrect, beak-like, or sometimes upwardly curved; three-segmented maxillary palpi, tympanal organs present at base of abdomen; and hindwings having $S_c + R_1$ fused with R_s beyond the cell (Common 1963).

Crambinae are Pyralidae that have a well developed cubital pecten (long hairs on Cu) in the hindwing, labial palpi that are very long and porrect, and maxillary palpi that are well developed, triangular in shape, and strongly dilated distally with scales.

Genus HEDNOTA Meyrick

Hednota Meyrick, 1886, Trans. Ent. Soc. Lond. 1886: 270.

Type species.—*Crambus bifractellus* Walker, 1863 (List Lep. Ins. Coll. Brit. Mus 27: 174) by subsequent designation.

In describing the genus, Meyrick mentioned two species, *Hednota bifractella* and *H. argyroëles*. He gave *H. bifractella* as an especial example of the genus, which, of course, does not constitute a valid type designation. The earliest references I found to the type of *Hednota* are Zimmerman's statements in "Insects of Hawaii" Vol. 8 (1958); where in p. 343 he figures the male genitalia of *H. bifractella* as, "the type of the genus *Hednota*", and in p. 347 he says, "I have checked the genitalia of the type of *Hednota* (*bifractella* Walker) . . ." I accept as a designation these statements of Zimmerman's that *H. bifractella* is the type of *Hednota*. The same species has been accepted as the type of *Hednota* by Bleszynski and Collins (1962).

Diagnosis.—M_1 of the hindwing remote from R_s and well removed from the upper angle of the cell, and in some this vein may be rudimentary or absent. Veins R_1 and R_5 are both present in the forewing, vein R_5 is not stalked with R_4 or R_3 (i.e. it arises separately from the cell) and in the hindwing M_2 is present (Fig.2). The frons is prominent and conical (Fig.3).

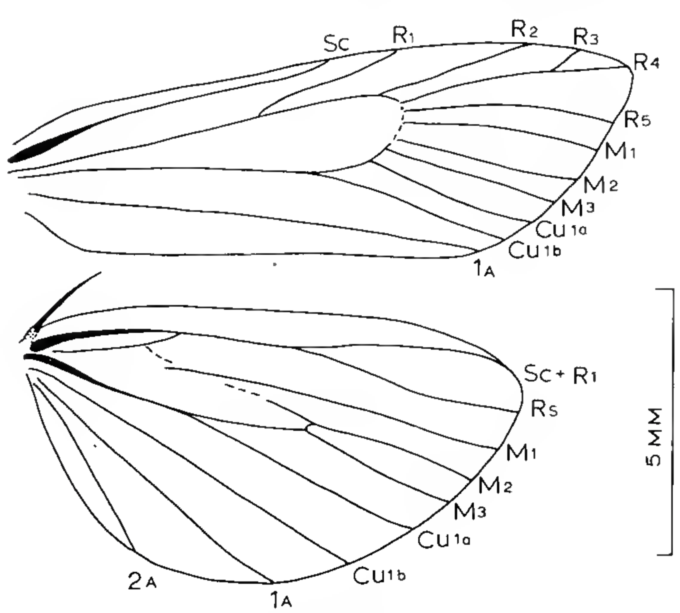

Figure 2.—Wing venation of *H. panteucha*, male, Koojan, W.A.

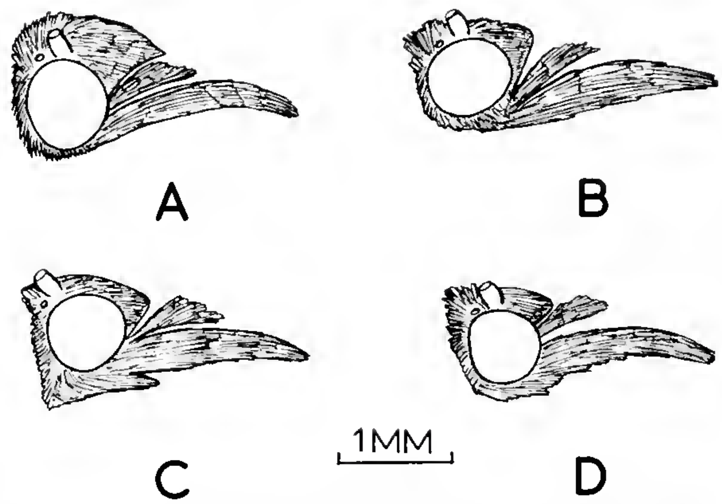

Figure 3.—Head and palpi of: A, *H. panteucha*, male, Koojan, W.A.; B, *H. longipalpella*, male, Nedlands, W.A.; C. *H. pedionoma*, male, Kojonup, W.A.; D. *H. crypsichroa*, male, Nedlands, W.A.

Comments.—The genus was formed by Meyrick to include all the Australian species (except *lativittalis* Walker) formerly classed by him under *Thisanotia* [misspelled by Meyrick as *Thinasotia*, see Bleszynski and Collins (1962, p. 314)].

Hednota panteucha (Meyrick), comb. nov.

Figs.2; 3A; 4A; 5A; 6A,B,C; 7A

Thinasotia [sic] *panteucha* Meyrick, 1885, Trans. Ent. Soc. Lond. 1885: 453.
Surattha penteucha [sic] (Meyrick). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 966.
Talis panteucha (Meyrick). Turner, 1904, Proc. Roy. Soc. Qd 18: 171.
Surattha panteucha (Meyrick). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 351.

Types.—Meyrick described the species from a single male, and the type-locality and comments were "Mount Lofty, South Australia; one specimen received from Mr. E. Guest, who took it in April, together with a second." The holotype is not in the British Museum (Natural History) (Whalley, personal communication).

Diagnosis.—This species can be distinguished from all other *Hednota* species, in the south-west of Western Australia, by the dark fuscous interveinal markings (Fig.4A) on the light yellow-ochreous ground colour of the forewing. The basal half of forewing veins M_5 to CU_b are dark fuscous; there is a streak of dark fuscous above submedian fold from near base to before middle, another streak beneath costal margin of cell from one-fourth (of length of cell from base) to transverse vein, and the dark fuscous reappears as a wider streak to before apex. The forehead has a large acute conical projection. Labial palpi ochreous, mixed with dark fuscous towards apex; white internally and ventrally at base behind eyes. The head is shown in Figure 3A. The antennae are dark fuscous, the male strongly bipectinate and with teeth with fine evenly but sparsely spaced hairs and apices of teeth not noticeably dilate (Fig.5A). Legs ochreous whitish suffused with fuscous. The wing venation is shown in Figure 2.

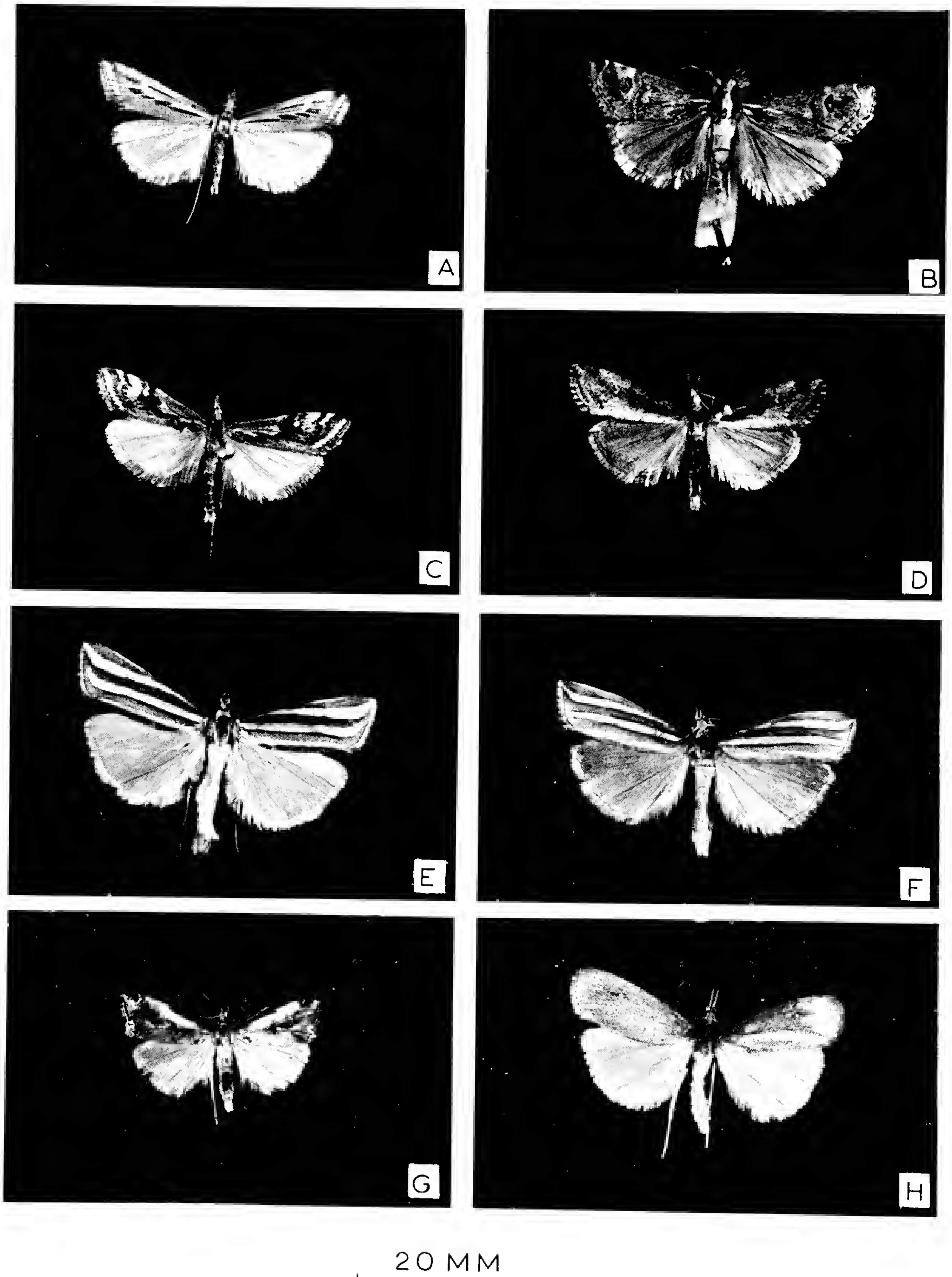

Figure 4.—A, *H. panteucha*, male, Parkside, S.A.; B, *H. longipalpella*, male, Nedlands, W.A.; C, *H. pedionoma*, male, Wongamine, W.A.; D, *H. crypsichroa*, male, Nedlands, W.A.; E, *H. recurvella*, male, Hamel, W.A.; F, *H. vittella*, male, Albany, W.A.; G, *H. dichospila*, male, Albany, W.A.; H, *H. vetustella*, male, Albany, W.A.

Figure 5.—Portion of antenna of male of: A, *H. panteucha*, Koojan, W.A.; B, *H. longipalpella*, Nedlands, W.A.; C, *H. pedionoma*, Kojonup, W.A.; D. *H. crypsichroa*, Nedlands, W.A.

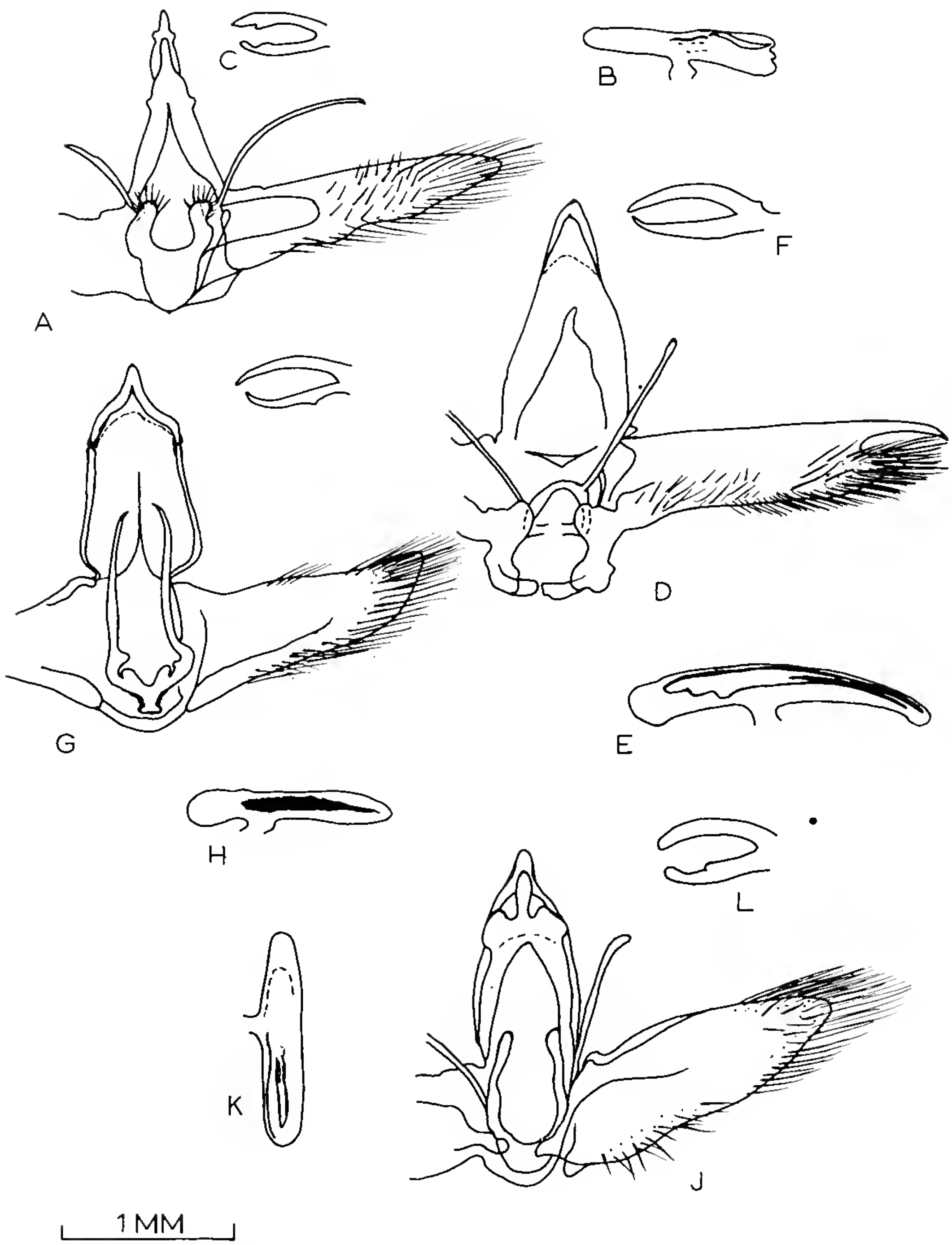

Figure 6.—Male genitalia of: A, B, C, *H. panteucha*, Koojan, W.A.; D, E, F, *H. longipalpella*, Koojan, W.A.; G, H, I, *H. pedionoma*, Koojan, W.A.; J, K, L, *H. crypsichroa*, Koojan, W.A.

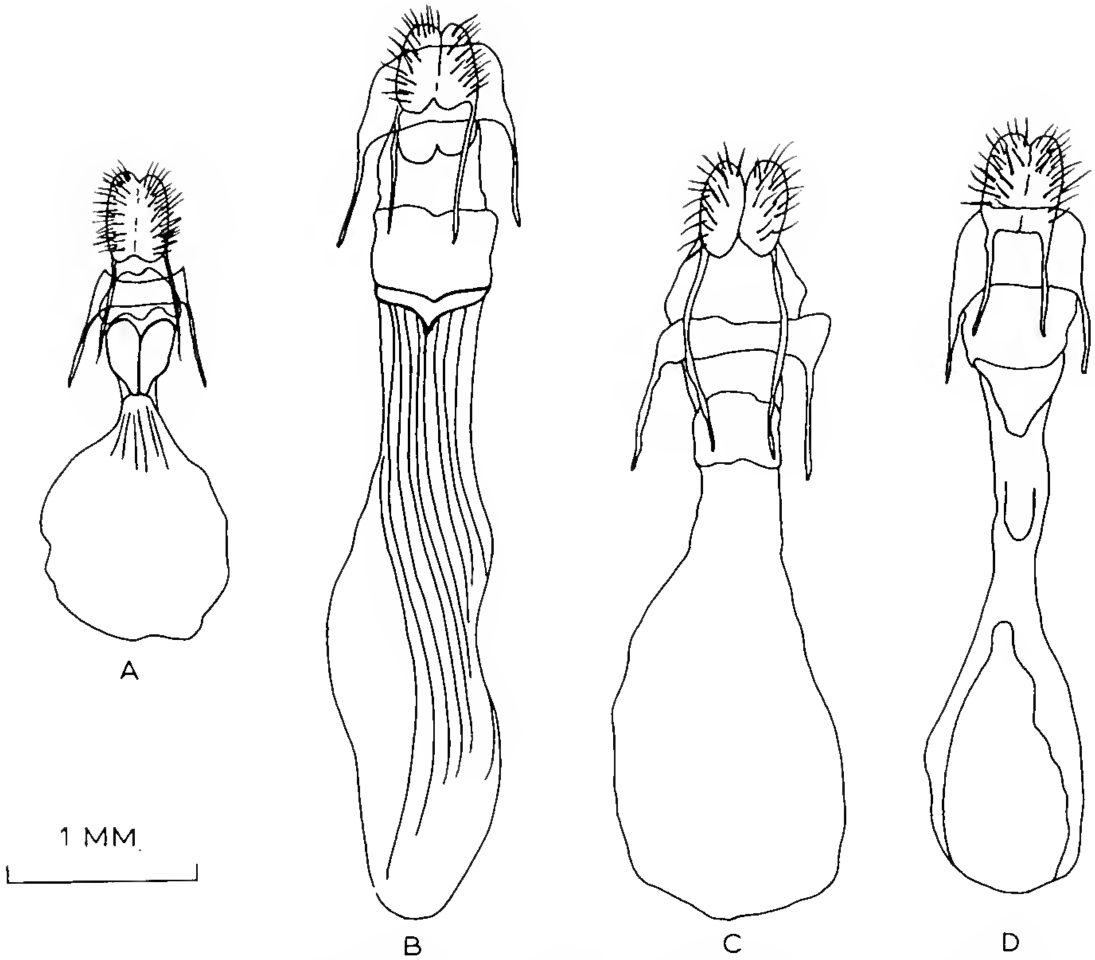

Figure 7.—Female genitalia of: A, *H. panteucha*, Koojan, W.A.; B, *H. longipalpella*, Koojan, W.A.; C, *H. pedionoma*, Kojonup, W.A.; D, *H. crypsichroa*, Kojonup, W.A.

Male genitalia (Fig.6A,B,C).—Uncus short, pointed, with a lateroventral bulge on each side; gnathos arms uniting gradually; anellar arms long, terminating in a slightly downwardly curved point; valva simple with costa nearly straight, dorsum wavy, apex tapering to a narrow rounded point; aedoeagus nearly straight.

Female genitalia (Fig. 7A).—Corpus bursae short and rounded; ductus bursae short with a few slightly sclerotized ribs; ostium bursae region strongly sclerotized, two distinct sclerotized plates rounded towards papillae anales, more pointed towards corpus bursae.

Expanse.—Male 21.0-25.5 mm, female 21.0-27.0 mm.

Specimens examined.—139♂, 80♀.

Queensland: Milmerran, Apr. 1946, J. Macqueen, 1♂ ANIC. New South Wales: Broken Hill, 16.ii. 1900, 1♂ SAM; 10.v.1912, 3♂ 1♀ SAM. Victoria: Birchip, Mar. 1899, D6, 1♂ ANIC; Mar. 1899, 1♂ NM; Mar. 1902, 2♀ ANIC; 9.iv. 1920, 1♂ 1♀ ANIC; Castlemaine, 5.iii.1908, 1♀ NM. Daytrap, 20.iii.1918, 1♂ AM; 20.iii.1918, 1♂ AM. Murtoa, 24.iii.1903, C.J.M., 1♂ ANIC, Nhill, 20.vi.1902, J.R.F., 1♂ ANIC. Walpeup, 23.iii.1920, 1♂ NM. South Australia; Adelaide (Waite Inst.), 26.iii.1958, 1♀ SAW; 20.iii.1959, 1♂ 2♀ SAW; 29.iii.1959, 1♀ SAW. Balhannah, 3.iv.1882, 1♂ SAM. Brentwood, 8.iv.1902, 1♂ ANIC. Crystal Brook, 24.iii.1962, MMHW, 6♂ 2♀ WAC. Parkside, 21.iii. 1892. 353, 1♂ SAM; 31.iii.1892, 1♂ 1♀ SAM; 20.iii.1900, 1♂ SAM 1.iv.1918, 1♀ SAM. Pinnaroo, 2♀ SAM. Tintinara/Bordertown, 27.iii.1962, MMHW. 2♀ WAC. Western Australia: Dumbleyung, 27.iii.1963, H. Udell, 1♂ 2♀ WAM. Goomalling, 18.iv.1951, CFHJ, 12♂ WADA; 14.iv.1952, DGS, 13♀ WADA; 15.iv.1952, DGS, 14♀ WADA; 16.iv.1952, DGS, 24♂ 2♀ WADA; 7.v.1952, PNF, 2♂ WADA; 14.iv.1953, DGS, 1♀ WAC. Kojonup, 1.iv.1959, MMHW, 1♂ ANIC; 1.iv.1959, 2♂ 1♀ WAC; 4.iv.1959, MMHW, 1♂ ANIC; 4.iv.1599, MMHW, 1♂ WAC; 24.iii.1960, JDB, 5♂ ANIC; 31.iii.1960, JDB, 2♂ANIC; 19.iii.1961, MMHW, 5♂ WAM; 21.iii.1961, MMHW, 2♂ 1♀ WAM; 19.iii.1963, ALR, 2♂ WAC; 22.iii.1963, MMHW, 3♂ WAM; 23.iii.1963, ALR, 1♂ WAC; 26.iii.1963, ALR 4♂ WAC; 30.iii.1963, ALR, 1♂ WAC. Koojan, 24.iii.1961, LEK, 2♂ WAM; 26.iii.1961, LEK, 2♂ WAM; 28.iii.1961, LEK, 5♂ 1♀ WAM; 23.iv.1961, LEK, 1♀ WAM; 28.iii.1963. LEK, 1♂ WAM; 29.iii.1963, LEK, 2♂ WAM; 8.iv.1963, LEK, 5♂ 1♀ WAM; 9.iv.1963, LEK, 5♂ 2♀ WAM. Moora, 18.iv.1961, JAB, 20♂ 20♀ WAM; 19.iv.1962, RWB, 3♂ 3♀ WADA. Toodyay, 19.iv.1951, CFHJ, 1♂ WADA.

Distribution.—Queensland: Milmerran. New South Wales: Broken Hill. Victoria: Birchip, Castlemaine, Daytrap, Murtoa, Nhill, Walpeup. South Australia: Adelaide, Balhannah, Brentwood, Crystal Brook, Mt. Lofty, Parkside, Pinnaroo, Tintinara/Bordertown. Western Australia: Dumbleyung, Goomalling, Kojonup, Koojan, Moora, Toodyay.

Comments.—In the original description of *panteucha*, Meyrick stated that vein 5 [= M_2] of the hindwing is absent. But vein M_2 is present, and this is a further reason why I include *panteucha* in *Hednota*. Meyrick (1885) described the species from Mt. Lofty, South Australia; and Turner (1904) included Mt. Lofty as a locality. The following are at the British Museum (Natural History) (Whalley, personal communication); 1 specimen "S Austral. Nick Dohrn, Jul. 81 (Zeller Coll. 1384)"; 1 specimen "Parkside, S. Australia, 99-49"; 9 specimens "Parkside, S. Australia, Rothschild Bequest, B.M. 1939-1 (one bears the no. 75)"; and 1 specimen "Pinnaroo, Coll. Lower, Suratha penteucha Meyr., Id. by N. B. Tindale".

Hednota longipalpella (Meyrick)

Figs.3B; 4B; 5B; 6D,E,F; 7B

Eromene longipalpella Meyrick, 1879, Proc. Linn. Soc. N.S.W. 3: 196-7.
Talis longipalpellus (Meyrick). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 969.
Talis longipalpella (Meyrick). Turner, 1904, Proc. Roy. Soc. Qd 18: 172.
Hednota longipalpella (Meyrick). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 351.

Types.—Meyrick described the species from an unspecified number of specimens and the type-locality and comment was "Near Melbourne; not scarce." One syntype is in the British Museum (Natural History) (Whalley, personal communication); I hereby designate as lectotype of *Eromene longipalpella* Meyrick this specimen, a female labelled "Melbourne, Victoria, G.H.R./78." Whalley has compared a slide of mine of female genitalia of a *longipalpella* against the genitalia of the lectotype and states, personal communication, that they agree exactly.

Diagnosis.—Forewing ochreous with some black and suffused with white; disc white and thickly and irregularly sprinkled with fine black; a transverse central fascia of the ochreous ground colour, sprinkled with whitish and blackish, gently angulated above and below middle, and bisected throughout by a violet-silvery metallic line; at two-thirds of disc, nearest to costa, is a crescentic violet-silvery metallic mark, margined with black internally and less strongly externally; a silvery metallic outwardly curved subterminal line (Fig.48B). Labial palpi twice as long as head (Fig.3B), whitish, mixed with dark fuscous, dark fuscous on sides, whitish ventrally towards base and white ventrally behind eyes. Antennae whitish ochreous, the male with wide teeth (Fig.5B). Legs are ochreous grey and there are ochreous white rings at the apices of tarsal joints. Wing venation essentially as in *H. panteucha* (Fig.2) but in the hindwings veins M_2 and M_3 do not leave the cell separately but are stalked for a short distance.

Male genitalia (Fig.6D,E,F).—Uncus and gnathos broad, sharply angled to apices; gnathos arms meeting abruptly; anellar arms straight, rounded at apices; anellus rounded towards gnathos; valva with costa nearly straight, then downcurved at apex to form a point, apex then has an inward arch which proceeds outwards to form a second more-rounded point of apex, dorsum slightly wavy; aedoeagus large, curved, with concave aspect on side of ductus ejaculatorius; cornutus as a pair of long thin horns, one somewhat longer and about twice as wide as other, both united at base.

Female genitalia (Fig.7B).—Corpus bursae elongate, rigid, somewhat sclerotized on part, with somewhat curved elongate ribs along its length; ostium bursae region strongly sclerotized, broader than deep, convex towards corpus bursae.

Expanse.—Male 18.0-26.2 mm, female 18.0-27.5 mm.

Specimens examined.—113♂, 98♀.

Queensland: Brisbane, 19.iii.1906, 1♂ ANIC; 20.iii.1906, 1♂ ANIC; 23.ii.1910, 1♂ ANIC; 11.iv.1921, 1♀ ANIC; 13.iii.1922, 1♀ ANIC; 6.iv.1943, 1♀ ANIC. Bunya Mts., 9.iii.1940, WBB, 1♂ QM; 21.ii.1940, 1♂ QM. Milmerran, 29.iii.1939, 1♀ ANIC. Stanthorpe, 8.ii.1930, WBB, 1♂ QM; 1♂ ANIC; Toowoomba, 1.iii.1921, WBB, 1♀ QM; 25.ii.1921, WBB, 1♂ QM; 10.iii.1931, 1♀ ANIC. New South Wales: Broken Hill, 4.iv.1890, 1♀ SAM; 2♂ 3♀ SAM. Scone 27.iii.1935, H. Nicholas, 1♂ ANIC. Australian Capital Territory: Black Mountain, 26.ii.1960, IFBC, 1♂ ANIC; 29.ii.1960, IFBC, 1♂ ANIC; 28.iii.1960, IFBC, 1♂ ANIC; 1.iv.1960, IFBC, 2♂ ANIC. Victoria: Birchip, 16.iv.1900, 1♂ ANIC. Towang, H. Jarvis, 1♀ QDAS. South Australia: Belair, 1♀ SAM; Blackwood, 2♀ SAM; Hallett, 17.xi.1893, 1♂ SAM; Parkside, 20.iii.1900, 1♂ SAM; Pinnaroo, 3♀ SAM. Western Australia: Albany, 4.iii.1926. WBB, 1♂ ANIC. Beverley, 3.iv.1962, JAB 1♀ WADA; 4.iv.1962, PJL, 5♀ WADA; 17.iv.1962, JAB, 1♂ 2♀ WADA. Darlington, 9.iv.1962, JAB, 1♀ WADA; Goomalling, 18.iv.1951, CFHJ, 1♂ WADA; 14.iv.1953, DGS, 2♂ 7♀ WADA; 16.iv.1953, DGS, 2♀ WADA; Kojonup, 1.iv.1959, MMHW, 5♀ WAC; 10.iv.1959, JDB, 1♀ WAC; 17.iii.1960, MMHW, 17♂ 3♀ WAM; 15.iii.1961, MMHW, 8♂ 2♀ WAM; 19.iii.1961, MMHW, 3♂ WAM; 21.iii.1961, MMHW, 6♂ WAM; 7.iv.1961, MMHW, 2♂ WAM; 14.iv.1962, MMHW, 2♀ WAM; 12iii.1963, ALR, 2♂ 10♀ WAC; 15.iii.1963, MMHW, 2♂ 1♀ WAM; 17.iii.1963, ALR, 3♂ 3♀ WAC; 22.iii.1963, MMHW, 10♂ WAM; 23.iii.1963, ALR, 3♂ 6♀ WAC; 30.iii.1963, ALR, 3♂ WAC; 3.iv.1963, ALR, 2♂ WAC. Koojan, 20.iii.1961, LEK, 1♂ WAM; 26.iii.1961, LEK, 1♀ WAM; 29.iii.1961, LEK, 1♂ WAM; 9.iv.1963, LEK, 2♂ 1♀ WAM; 4.v.1961, LEK, 1♂ WAM. Merredin, 23.iv.1962, AS, 3♀ WADA; 23.iv.1962, JAB, 1♀ WADA. Moora, 11.iv.1962. PJL 1♂ 1♀ WADA. Nedlands, 28.iii.1959, MMHW, 4♂ WAC; 29.iii.1959, MMHW, 1♀ WAC; 31.iii.1959, MMHW, 1♀ WAC; 3.iv.1959, MMHW, 3♂ WAC; 7.iv.1959, MMHW, 2♀ WAC; 19.iii.1961, MMHW, 1♂ ANIC; 21.iii.1961, MMHW, 1♀ ANIC; 22.iv.1961, MMHW, 1♂ ANIC; 10.iv.1962, MMHW, 1♀ WAC; 18.iii.1963, 2♀ WAC; 23.iii.1963, MMHW, 1♂ 2♀ WAC; 25.iii.1963, MMHW, 1♂ 1♀ WAC; 26.iii.1963, MMHW, 1♂ WAC; 27.iii.1963, 1♀ WAC; 28.iii.1963, MMHW, 1♀ WAC; 30.iii.1963, 1♂ 1♀ WAC; 31.iii.1963, MMHW, 2♂ 2♀ WAC; 5.iv.1963, MMHW, 6♂ 3♀ WAC. Perth, Mathews, 1♀ ANIC. Roleystone, 3.iv.1962, LEK, 1♂ 1♀ WAM. Swan R., J. Clark, 1♀ ANIC. Three Springs, 6.iv.1962, JAB, 1♀ WADA.

Distribution.—Queensland: Brisbane, Bunya Mts., Milmerran, Stanthorpe, Toowoomba, Wallangarra. New South Wales: Broken Hill, Scone. Australian Capital Territory: Black Mountain. Victoria: Birchip, Brentwood, Melbourne, Towang. South Australia: Belair, Blackwood, Hallett, Parkside, Pinnaroo, Stephenson River. Western Australia: Albany, Beverley, Darlington, Goomalling, Kojonup, Koojan, Merredin, Moora, Nedlands, Perth, Roleystone, Swan River, Three Springs.

Comments.—When Meyrick described *longipalpella* he included *bifractella* in a key with it, treating both as *Eromene* species. Lower (1896, p. 252) gave Stephenson River (South Australia) as a locality, and Turner (1904) gave Melbourne and Brentwood (Victoria). The following are at the British Museum (Natural History) (Whalley, personal communication): 1 specimen "Melbourne, Victoria, G.H.R./78" (lectotype of *Eromene longipalpalpella*); and 1 specimen "Wallangarra, Queensland, A.J.T./95 (abdomen missing)".

Hednota pedionoma (Meyrick)

Figs.3C; 4C; 5C; 6G,H,I; 7C

Thinasotia [sic] *pedionoma* Meyrick, 1885, Trans. Ent. Soc. Lond. 1885: 453.
Talis pedionoma (Meyrick). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 968.
Talis pediononoma [sic] (Meyrick). Turner, 1904, Proc. Roy. Soc. Qd 18: 173.
? *Metasia bilunalts* Hampson, 1913, Ann. Mag. Nat. Hist. (8) 12: 4. [syn. ?, nov.]
Hednota pedionoma (Meyrick). Blenszynski and Collins, 1962, Acta Zool. Cracov. 7: 316.

Types.—The species was described by Meyrick from an unspecified number of specimens of both sexes, and type-localities and comments were "Bathurst, New South Wales (2100 feet);

Mount Lofty, South Australia; in April, locally common in dry grassy places." Seven syntypes are in the British Museum (Natural History) (Whalley, personal communication). Following Whalley's selection, I hereby designate as lectotype of *Thinasotia pedionoma* Meyrick one of these specimens, a male labelled "Bathurst, N.S.Wales, grass, 15/4/79, B.M. slide No. 3971"; I have examined this genitalia slide. The holotype of *Metasia bilunalis* at the British Museum (Natural History) appears externally the same as *pedionoma* (Bleszynski, personal communication), and I therefore include it above as a possible synonym. Confirmation will have to await critical examination of its genitalia.

Diagnosis.—Forewing narrow, light fuscous and white, costal half suffused with ochreous towards base. Two obscure blackish parallel lines from middle of costa parallel to termen, indented costally to middle, not passing submedian fold, towards costa from middle both are bent inwards and coalesce to form a short black streak pointing towards base; a small roundish white, blackish-margined, discal spot; a short whitish streak from costa at five-sixths, preceded and followed by a darker suffusion on costa (Fig.4C). Forehead has a short cone (Fig. 3C). Labial palpi ochreous mixed with dark fuscous towards apex; white internally, and ventrally to behind eyes. Antennae grey, the male strongly dentate and with the apices of teeth moderately hairy (Fig.5C). Legs fuscous, but whitish ventrally. Wing venation essentially as in *H. panteucha* (Fig.2).

Male genitalia (Fig.6G,H,I).—Gnathos and uncus sharply curved inwards towards apices; apex of uncus rounded; gnathos arms uniting very gradually, with a backwardly pointing ventral bulge on each; anellar arms gradually tapering to inwardly turned points at apices; valva short, costa nearly straight, dorsum somewhat sharply upturned at apex, which is rounded; aedoeagus with cornutus as a long very pointed horn consisting of numerous fine thorns pointing towards apex.

Female genitalia (Fig.7C).—Corpus bursae large, somewhat rounded; ostium bursae region strongly sclerotized, about as deep as broad; ductus bursae short, not sclerotized.

Expanse.—Male 18.8-25.4 mm, female 17.0-23.1 mm.

Specimens examined.—180 ♂, 86 ♀.

New South Wales: Armidale, 3.iv.1963, R. J. Roberts, 1♀ WAC. Killara, 23.iv.1920, 1♂ AM. Leura, 12.iv.1914, 1♂ AM. National Park (Sydney), 11.iv.1925, 1♀ AM; 25.iv.1925, 1♀ AM. Sydney, 28.iii.1941, 1♀ AM. Australian Capital Territory: Black Mountain, 28.iii.1951, IFBC, 3♀ ANIC; 4.iii.1960, IFBC, 1♂ ANIC; 28.iii.1960, IFBC, 1♂ 1♀ ANIC; 30.iii.1960, IFBC, 1♀ ANIC; 29.iii.1963, IFBC, 1♀ ANIC. Victoria: Birchip, 15.iv. 1903, 1♂ NM; 20.iv.1903, 1♂ ANIC; 20.iv.1903, 1♀ NM; 18.iv.1904, 1♀ NM; 9.iv.1920, 3♀ ANIC; 10.ix.1920, 1♂ ANIC. Castlemaine, 3.iv.1907, W. E. Drake, 1♀ ANIC. Chelsea, 29.iii.1921, 1♂ NM. Cheltenham, 24.iv.1921, 1♂ NM. Croydon, 29.iii.1908, S. W. Fulton, 1♀ NM. Dunkeld, 17.iv.1923, 1♂ 2♀ ANIC. Gisborne, 30.iii.1908, G. Lyell, 1♀ NM. Glenelg, 7.iv.1923, 1♀ ANIC. Kerang, 10.iv.1951, C. J. R. Johnston, 1♀ QDAS. Moe, 28.iii.1934, C. G. L. Gooding, 1♀ QM. N. Melbourne 2♂ NM. Sea Lake, 29.iii.1906, 1♀ NM. Wimmera, H320, 1♂ SAM. Tasmania: Hobart, 1♀ ANIC. Launceston, 1.iv.1961, F. M. Littler, 1♂ 1♀ SAM. Mt. Barrow, 2500 ft, 3.iii.1963, IFBC and MSU, 1♂ ANIC. Pyengana, 1000 ft, 2.iii.1963, IFBC and MSU, 1♂ ANIC. Waratah, 3 miles E. of, 2000 ft, 17.ii.1963, IFBC and MSU, 2♂ ANIC. Westbury, 13 miles S. of, 4.iii.1963, IFBC and MSU, 1♂ ANIC. K 10226, 2♂ AM. South Australia: Blackwood, 1♂ SAM; 343, 1♂ SAM. Parkside, 31.iii.1892, 1♂ SAM; 1♂ SAM. Pinnaroo, 1♂ 3♀ SAM. Western Australia: Beverley, 11.iv.1962, PJL, 2♂ 5♀ WADA; 17.iv.1962, PJL, 1♂ 1♀ WADA; 20.iv.1962, PJL, 3♂ WADA; 24.iv.1962, PJL, 1♂ 1♀ WADA; 27.iv.1962, PJL, 4♂ WADA. Denmark, 27.iii.1926, WBB, 1♂ 1♀ ANIC; 29.iii.1926 WBB, 1♀ ANIC; 4.iv.1926, WBB, 1♀ QM; 5.iv.1926, WBB, 1♂ ANIC; 5.iv.1926, WBB, 3♀ QM; 7.iv.1926, WBB, 1♀ QM; 13.iv.1926, WBB, 1♂ ANIC; 13.iv.1926, WBB, 1♀ QM. Goomalling, 16.iv.1951, DGS, 4♂ WADA; 18.iv..1951; CFHJ, 14♂ WADA; 2.v.1952, PNF, 2♂ WADA; 5.v.1952, PNF, 1♀ WADA; 7.v.1952, PNF, 5♂ WADA; 14.iv.1953, DGS, 1♀ WADA; 16.iv.1953, DGS, 4♀ WADA. Katanning, 22.iv.1950, JAM, 4♂ 1♀ WADA; 15.iv.1951, MMHW, 1♂ WAC; 22.iv.1951, JAM, 1♂ ANIC. Kojonup, 1.iv.1959, MMHW, 2♂ WAC; 4.iv.1959, MMHW, 6♂ WAC; 10.iv.1959, JDB, 2♂ 7♀ WAC; 17.iv.1959, MMHW, 1♂ WAC; 21.xi.1959, MMHW, 1♂ ANIC; 31.iii.1960, JDB., 2♂ 1♀ ANIC; 6.iv.1961, MMHW, 1♂ WAM; 14.iv.1962, MMHW, 15♂ 2♀ WAM; 21.iii.1963, MMHW, 3♂ 1♀ WAM; 23.iii.1963, ALR, 4♂ WAC; 3.iv.1963, ALR, 3♂ WAC; 12.iv.1963, ALR, 1♂ WAC; 21.iv.1963, MMHW, 9♂ 1♀ WAM. Koojan, 22.iv.1961, LEK, 1♂ WAM; 23.iv.1961, LEK, 3♂ 1♀ WAM; 24.iv.1961, LEK, 1♂ WAM; 27.iv.1961, 4♂ WAM; 4.v.1961, LEK, 1♂ WAM; 8.iv.1963, LEK, 8♂ 1♀ WAM; 9.iv.1963, LEK, 3♂ 3♀ WAM. Merredin, 23.iv.1962, AS, 1♂ 2♀ WADA. Moora, 19.iv.1962, RWB, 3♂ 5♀ WADA. Mt. Ragged, 17 mi. N. of, 25.iv.1962, AMD, 2♀ WAM. Mukinbudin, 20.v.1959, S. J. Lavery, 1♀ WADA. Nedlands, 16.iv.1959, MMHW, 2♂ WAC; 17.iv.1959, MMHW, 1♂ WAC. Port Malcolm, 25.iv.1962, AMD, 1♂ WAM. Swan R., LJN, 1♂ ANIC; LJN, 1♂ WADA. Toodyay, 19.iv.1951, CFHJ, 2♂ WADA; 4.v.1952, CFHJ, 4♂ 1♀ WADA; 10.iv.1953, 7♂ 6♀ WADA; 13.iv.1953, CFHJ, 1♂ WADA; 15.iv.1953, LJ, 5♂ WADA; 20.iv.1953, LJ, 5♂ WADA; 1.iv.1959, CFHJ, 2♂ WADA. Wongamine, 13.iv.1960, JAM, 2♂ ANIC.

Distribution.—New South Wales: Armidale, Bathurst, Killara, Leura, Sydney. Australian Capital Territory: Black Mountain. Victoria: Birchip, Castlemaine, Chelsea, Cheltenham, Croydon, Dunkeld, Gisborne, Glenelg, Kerang, Moe, Melbourne, N. Melbourne, Sea Lake, Wimmera. Tasmania: Hobart, Launceston, Mt. Barrow, Pyengana, Waratah, Westbury. South Australia: Adelaide, Blackwood, Mt. Lofty, Parkside, Pinnaroo. Western Australia: Beverley, Bridgetown, Denmark, Goomalling, Katanning, Kojonup, Koojan, Merredin, Moora, Mt. Ragged, Mukinbudin, Nedlands, Port Malcolm, Swan River, Toodyay, Wongamine.

Comments.—Meyrick (1885) gave Mt. Lofty (South Australia) as a locality, Meyrick (1887) gave Wimmera (Victoria), Turner (1904) gave Bathurst (New South Wales), and Turner (1905) gave Bridgetown (Western Australia). The following are at the British Museum (Natural History) (Whalley, personal communication): 1 specimen "2940, Victoria, 89.114. Metasia bilunalis ♂ Hmpsn. Type"; 5 specimens "Bathhurst, N.S.Wales, grass, 15.4.79 (one specimen with abdomen missing, one dissected Brit-Mus. Slide No. 3971)" (4 paralectotypes, and lectotype of *Thisanotia pedionoma*); 2 specimens "Mt. Lofty. S. Australia, O.T./82 (one specimen bears the following data: Australia 96.182, *Talis pedionoma* Meyr.)" (paralectotype of *Thisanotia pedionoma*); 2 specimens "Melbourne, Victoria, W./93 (both without abdomen.)"; 1 specimen "Blackwood, S. Australia, O.L./98"; 2 specimens "Victoria SB./91 (one with abdomen missing)"; 1 specimen "Adelaide, S. Australia, R. .07, Brit. Mus. Slide No. 3972"; 8 specimens "Parkside, S. Australia, Rothschild Bequest, B.M. 1939-1 (four of these specimens bear the no. 73; one of these bears the following label: 97.23)"; 1 specimen "Bath. A16, '79"; and 1 specimen without data.

Hednota crypsichroa Lower

Figs.3D; 4D; 5D; 6J,K,L; 7D

Hednota crypsichroa Lower, 1893, Trans. Roy. Soc. S. Aust. 17: 166.

Prosmixis discilunalis Hampson, 1919, Ann. Mag. Nat. Hist. (9) 4: 147.

Talis crypsichroa (Lower). Turner, 1904, Proc. Roy. Soc. Qd 18: 174.

Hednota crypsichroa Lower. Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 314.

Types.—Lower described both sexes from an unspecified number of specimens, and the type-localities and comments were "Blackwood, Parkside, and Belair, usually at light, in March and April. An obscure though distinct species." I have dissected the genitalia of a South Australian Museum specimen, a male, labelled "Parkside" and "Type", which I hereby designate as lectotype of *Hednota crypsichroa* Lower.

Hampson (1919) gave the type-locality and comments for the synonym, *Prosmixis discilunalis,* as follows: "Victoria, Melbourne (Anderson), 1♂ type. Exp. 22 mm." The holotype, which is in the British Museum (Natural History) (Whalley, personal communication), has not been examined by me. But Whalley has compared a slide of mine of the male genitalia of *crypsichroa* with the genitalia of the holotype of *P. discilunalis* (Brit. Mus. Slide No. 7112) and states, personal communication, that they agree exactly.

Diagnosis.—Forewing varies from ochreous white to fuscous, usually with a suffused blackish streak along fold from base towards tornus; a transverse elongate discal spot, outlined with blackish, beyond middle, generally suffusedly bordered on either side with fuscous patches (Fig.4D). Labial palpi two to three times as long as head (Fig.3D), whitish ochreous, fuscous tinged, fuscous beneath. Antennae light fuscous, the male with teeth about as wide at base as the distance between teeth (Fig.5D). Legs whitish, fuscous tinged. Wing venation essentially as in *H. panteucha* (Fig.2).

Male genitalia (Fig.6J,K,L).—Uncus short, rounded; gnathos rounded, along each arm of gnathos there is a lobe, which shows as an inward bulge from lateral view; anellar arms curved and rounded at apices; valva short, broad at base tapering somewhat sharply to apex; aedoeagus with cornutus as two somewhat short horns.

Female genitalia (Fig.7D).—Corpus bursae with internal sclerotization; ductus bursae long, with some sclerotization; ostium bursae region triangular with apex pointing towards corpus bursae.

Expanse.—Male 19.7-24.0 mm, female 19.2-29.0 mm.

Specimens examined.—143♂, 49♀.

New South Wales: Broken Hill, 10.v.1912, 1♂ 2♀ SAM; 10.iv.1913, 1♂ SAM; 10.iv.1963, 1♂ SAM; 10♀ SAM. Australian Capital Territory: Black Mountain, 4.iii.1960, IFBC, 1♂ ANIC; 7.iii.1960, IFBC, 1♂ ANIC. Victoria: Birchip, Mar. 1902, 1♂ ANIC; 3.iii.1920, 6♂ 1♀ ANIC; 27.iii.1920, 1♂ ANIC; 30.iii.1920, 1♂ QM. Castlemaine, 21.iii.1907, 1♂ NM. Gisborne, 16.iii.1900, 1♂ ANIC. Sea Lake, 24.iii.1906, 1♂ 1♀ NM. Walpeup, 12.iv.1920, 1♀ NM. South Australia: Blackwood, 2♂ SAM. Crystal Brook, 24.iii.1962, MMHW, 1♂ 1♀ WAC. Parkside, 22.iii.1892, 300, 1♂ SAM; 4.iv.1919, 2♂ SAM; 6.iv.1919, 1♀ SAM; 1361, 1♂ SAM; 1♂ (lectotype of *Hednota crypsichroa*) SAM. Pinnaroo, 20.v.1915, 1♂ SAM. Tintinara/Bordertown, 27.iii.1962, MMHW, 1♀ WAC. Yorke Peninsula, 24.iii.1891, 1♀ SAM; 25.ii.1896, 1♀ SAM; 11.iii.1896, 1♂ SAM; 17.iii.1896, 1♂ SAM. Western Australia: Beverley, 5.iv.1962, PJL, 1♂ WADA; 12.iv.1962, PJL, 1♂ WADA; 17.iv.1962, PJL, 1♂ WADA; 27.iv.1926, PJL, 1♂ WADA. Denmark, 19.iii.1926, WBB, 1♂ ANIC; 26.iii.1926, WBB, 1♂ 1♀ QM; 27.iii.1926, WBB, 3♂ QM; 28.iii.1926, WBB, 1♂ QM; 30.iii.1926, WBB, 2♂ ANIC; 2.iv.1926, WBB, 1♂ ANIC; 2.iv.1926, WBB, 1♂ ANIC; 3.iv.1926, WBB, 1♀ ANIC; 3.iv.1926, WBB, 2♂ QM; 4.iv.1926, WBB, 1♂ ANIC; 4.iv.1926, WBB, 1♀ QM; 5.iv.1926, WBB, 1♀ ANIC. Donnybrook, Apr. 1928, 2♂ NM. Goomalling, 14.iv.1953, DGS. 2♂ WADA; 18.iv.1951, CFHJ, 4♂ WADA. Katanning 15.iv.1951, MMHW, 1♀ WAC. Kojonup, 1.iv.1959, MMHW, 4♀ WAC; 4.iv.1959, MMHW, 1♂ WAC; 9.iv.1959, JDB, 3♂ WAC; 10.iv.1959, JDB, 1♂ 8♀ WAC; 17.iii.1960, MMHW, 10♂ WAM; 22.iii.1961, MMHW, 6♂ 1♀ WAM; 6.iv.1961, MMHW, 11♂ 1♀ WAM ;14.iv.1962, MMHW, 1♀ WAM; 12.iii.1963, ALR, 5♂ 2♀ WAC; 23.iii.1963, ALR 3♂ 1♀ WAC; 30.iii.1963, ALR, 5♂ WAC. Koojan, 18.iii.1961, LEK, 4♂ WAM; 20.iii.1961, LEK, 15♂ WAM; 4.iv.1963, LEK 4♂ WAM; 8.iv.1963, LEK, 3♂ WAM; 9.iv.1963, LEK, 4♂ WAM. Moora, 19.iv.1961, JAB, 1♀ WADA; 11.iv.1963, PJL, 3♂ WADA. Nedlands, 2.iv.1959, MMHW, 2♂ WAC; 6.iv.1959, MMHW, 1♀ WAC; 16.iv.1959, MMHW, 2♂ 1♀ WAC; 27.iii.1961, MMHW, 1♂ ANIC; 30.iii.1961, MMHW, 1♂ ANIC; 5.iv.1962, MMHW, 1♂ ANIC; 29.iii.1963, MMHW, 1♂ WAC. Roleystone, 3.iv.1962, LEK, 1♂ 1♀ WAM. Three Springs 1.iv.1962, JAB, 2♀ WADA; 9.iv.1962, JAB, 1♂ WADA. Toodyay, 4.v.1952, CFHJ, 1♂ WAC. Waroona, Apr. 1907, GFB, 1♂ NM.

Distribution.—New South Wales: Broken Hill. Australian Capital Territory: Black Mountain. Victoria: Birchip, Castlemaine, Gisborne, Melbourne, Sea Lake, Walpeup. South Australia: Adelaide, Belair, Blackwood, Crystal Brook, Mt. Lofty, Parkside, Pinnaroo, Tintinara/Bordertown, Yorke Peninsula. Western Australia: Beverley, Denmark, Donnybrook, Goomalling, Katanning, Kojonup, Koojan, Moora, Nedlands, Roleystone, Three Springs, Toodyay, Waroona.

Comments.—Appearance of forewing variable, but distinguishable mainly by the transverse elongate discal spot, which is usually suffusedly bordered on either side with fuscous patches; and often distinguishable by the presence of the suffused blackish streak along fold from base towards tornus. This blackish streak is, as a rule, not as dark as the black streak pointing towards base in the forewing of *H. pedionoma*. Lower (1893) gave Belair (South Australia) as a locality, and Turner (1904 and 1937) gave Adelaide and Mount Lofty (South Australia). The following specimen is at the British Museum (Natural History) (Whalley, personal communication): "Nr. Melbourne, Victoria, I-III.90 Anderson 1890, Talis discilunalis type ♂ Hmpsn. Pyralidae, Brit. Mus. Slide No. 7112."

Hednota recurvella (Walker)

Fig.4E

Crambus recurvellus Walker, 1863, List Lep. Ins. Coll. Brit. Mus. 27: 171.

Talis recurvellus (Walker). Hampson, 1896, Proc. Zool Soc. Lond. 1895: 968.

Talis recurvellus (Walker). Turner, 1904, Proc. Roy. Soc. Qd 18: 172.

Hednota recurvellus (Walker). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 317.

Types.—Type-locality "West Australia". Described by Walker from the female "from Mr. Clifton's collection". The holotype (label data "W. Australia 47/109") (abdomen missing) is in the British Museum (Natural History) (Whalley, personal communication). Also see comments under next species, *H. vittella*.

Diagnosis.—This species can be distinguished from all other *Hednota*, in the south-west of Western Australia, in that the two main stripes on the forewing are both sharply recurved towards the apex (Fig. 4E). The bright apricot background colour of the forewing is also a prominent characteristic. The thorax has a bright apricot stripe on each side.

Specimens examined.—19♂, 16♀.

Western Australia: Applecross, Feb. 1956, DGS 1♀ WADA. Capel, Jan. 1944, PNF, 1♀ WADA. Hamel, 14.xii.1913, R.I., 2♂ ANIC; 14.xii.1913, R.I., 1♂ QM; 14.xii.1913, R.I., 2♂ SAM; 30.xii.1913, 2♂ SAM. Koojan, 24.iii.1961, LEK, 1♀ WAM. Nedlands, 19.i.1961, MMHW, 1♂ ANIC; 21.ii.1961, MMHW, 1♀ ANIC; 28.ii.1961, MMHW, 1♂ ANIC; 30.xi.1961, JAM, 1♂ ANIC. Perth, 7.i.1926, WBB, 1♂ QM; 25.xi.1938, 1♀ ANIC; 3537, 1♂ SAM; 1♀, SAM. Swan R., LJN, 2♀ WADA. W. Perth, 29-1491, 1♀ WAM. Walpole, 15 mi. N.W. of, 15.xi.1958, IFBC, 2♂ 1♀ ANIC. Wanneroo, 15.iv.1963, GSMC, 1♀ WAC. Waroona, 13.xii.1906, GFB, 1♀ ANIC; 30.xii.1907, GFB, 1♀ ANIC; 18.xii.1907, GFB, 1♀ AM; 10.i.1908, GFB, 1♀ AM; 27.xi.1913, GFB, 1♂ AM; 28.xi.1913, GFB, 1♂ AM; 13.i.1926, WBB, 1♂ QM. J. Clark, 1♂ NM. K 10233, 1♂ AM. 23-14, 1♀ WAM.

Comments.—See under next species, *H. vittella*.

Hednota vittella (Suederus)

Fig.4F

Tinca vittella Suederus, 1787, Act. Holm.: 227.
?*Tinea bivittella* Donovan, 1805, Ept. N.H.Ms. New Holland.
?*Crambus trivittatus* Zeller, 1863, Chil. Cramb. Gen. Spec.: 34.
Crambus bivitella [sic] (Donovan). Walker, 1863, List Lep. Ins. Coll. Brit. Mus. 27: 171.
Talis bivittellus (Donovan). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 968.
Crambus trivittalis Zeller. Hampson, 1896, Proc. Zool. Soc. Lond. 1895; 968. (Misspelling of *trivittatus;* according to Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 317.)
Talis bivittella (Donovan). Turner, 1904, Proc. Roy. Soc. Qd 18: 172.
Hednota vittella (Suederus). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 317.

Types.—See comments.

Diagnosis.—Distinguished from all other *Hednota* species, in the south-west of Western Australia, in that only the first of the two main stripes on the forewing is recurved upwards towards the apex; the second is slightly downcurved (Fig.4 F). Background colour of forewing yellowish brown. The thorax has a yellowish brown stripe on each side.

Specimens examined.—6♂, 4♀.

Western Australia: Albany, 5.iii.1926, WBB, 1♂ QM. Applecross, Mar. 1951, W. M. O'Donnell, 3♀ WADA. Beverley, F. H. du Boulay, 1♂ SAM. Cunderdin, 9.vi.1913, S. Lundy, 7258, 1♂ WAM. Mt. Barker, LJN, 1♂ WADA. Nedlands, 16.iv.1960, MMHW, 1♂ ANIC. Wanneroo, 27.iv.1963, GSMC, 1♂ WAC. K 10228, 1♂ AM.

Comments.—In the literature, the identity of this species and that of the previous one, *H. recurvella*, has been badly confused. Meyrick (1879) considered *Crambus recurvellus* Walker to be a synonym of *Tinea bivittella* Donovan, and considered that Walker (1863) confused *bivitellus* and *trivittatus*. The sorting of the problem of the identity of *H. recurvella* and *H. vitella* in the literature cannot be achieved without a special investigation of the literature and the types. Therefore the first three citations of the synonymy I give above for *H. vittella* are a direct copy from Bleszynski and Collins (1962, p. 317). I have not examined any of the types of the species in the synonymy and I have not seen the description by Suederus, Donovan or Zeller. To avoid complication, I have excluded the views of Meyrick (1879) from the synonymy for *H. recurvella* and *H. vittella;* and to clarify the situation, I compare his names with my present classification and that of Walker (1863) in Table 1.

Table 1

H. recurvella *and* H. vittella *compared with the classifications by Meyrick and Walker*

Koch (this paper)	Meyrick (1879)	Walker (1863)
Hednota recurvella (Walker)	*Crambus bivittellus* (Donovan) Syn.: *Crambus recurvellus* Walker	*Crambus recurvellus*, sp. nov.
Hednota vitella (Suederus)	*Crambus trivittatus* (Zeller) Syn.: *vivittellus** (Walker)	*Crambus bivitella* (Donovan)

* I have been unable to trace this name [LEK].

Hednota dichospila (Turner)

Fig.4G

Talis dichospila Turner, 1937, Proc. Soc. Qd 48: 67.
Hednota dischospila (Turner). Blesxynski and Collins, 1962, Acta Zool. Cracov. 7: 315.

Types.—The species was described from one female received by Turner from Mr. W. H. Mathews from Perth, Western Australia. I have examined the holotype (label data "Perth, W.A., Mathews") in the Australia National Insect Collection.

Diagnosis.—Can be distinguished from the other *Hednota* species, in the south-west of Western Australia, by the markings on the forewing which are: the dark fuscous costal streak from base to three-fifths, suffusedly edged with whitish, which extends on costa to four-fifths; the small fuscous transverse mark in disc at one-third, and a larger one at two-thirds; the slender white subterminal line inwardly oblique from costa before apex, soon curved outwards and sinuate to tornus; the white apical spot preceded by a fuscous costal spot; and the pair of blackish-edged distinct white spots on terment just above tornus (Fig.4G). Antennae fuscous, the male strongly bipectinate.

Specimens examined.—6♂, 7♀.

Western Australia: Albany, 23.ii.1926, WBB, 1♂ QM; 1.iii.1926, WBB, 1♂ ANIC; 3.iii.1926, WBB, 1♂ ANIC; 4.iii.1926, WBB, 1♂ QM. Denmark, 17.iii.1926, WBB, 1♂ QM; 25.iii.1926, WBB, 1♀ ANIC; 28.iii.1926, WBB, 1♀ ANIC. Kojonup, 21.iii.1961, RJP, 1♀ ANIC. Nedlands, 28.iii.1963, MMHW, 1♀ WAC; 5.iv.1963, MMHW, 1♀ WAC. Perth, Mathews, 1♀ (holotype of *Talis dichospila*) ANIC. Wanneroo, 29.iii.1962, GSMC, 1♂ ANIC; 3.iv.1962, GSMC, 1♀ ANIC.

Hednota vetustella (Walker)

Fig.4H

Crambus vetustellus Walker, 1863, List Lep. Ins. Coll. Brit. Mus. 27: 176.
? *Crambus demissalis* Walker, 1863, List. Lep. Ins. Coll. Brit. Mus. 27: 176.
Hednota asterias Meyrick, 1887, Trans, Ent. Soc. Lond. 1887: 250.
Hednota vetustellus (Walker). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 317.

Types.—*C. vetustellus* and *C. demissalis* were both described by Walker from the male, and the type-locality and comments were "Swan River, Presented by Sir J. Richardson." *H. asterias* was described by Meyrick from the male, and the type-locality and comments were "Albany, West. Australia; one specimen in December". The holotypes of *C. vetustellus* (label data "Swan River 43/14") (abdomen missing) and *H. asterias* (label data "Albany, W. Australia 2/12/86; B.M. Pyralidae Slide No. 7136 ♂; 231 Bleszynski 195"), but not of *C. demissalis*, are at the British Museum (Natural History) (Whalley, personal communication). Also see comments.

Diagnosis.—Distinct from all other Western Australian *Hednota* species, in that the forewing has a rounded apex, is dark cinereous, minutely black-speckled along the veins, and has a whitish discal point (Fig. 4H).

Specimens examined.—4♂, 4♀.

Western Australia: Albany, 15.ii.1926, WBB, 1♀ ANIC; 15.ii.1926, WBB, 1♂ QM; 19.ii.1926, WBB, 1♂ QM; 21.ii.1926, WBB, 1♀ ANIC; 23.ii.1926, WBB, 1♂ ANIC; 22.iii.1926, WBB, 1♀ QM; 27.iii.1926, WBB, 1♀ QM. Denmark, 17.iii.1926, WBB, 1♂ ANIC.

Comments.—Bleszynski and Collins (1962 p.317) consider *asterias* a synonym of *vetustella*. The description of *asterias* applies to *vetustella*, and I too consider *asterias* to be a synonym of *vetustella*.

In this paper, I include *C. demissalis* as a possible synonym of *H. vetustella*. However, I have been unable to find any specimens fitting the description of *C .demissalis*, which has been included in *Hednota* by Bleszynski and Collins (1962). Meyrick (1887) stated that *C. demissalis* was represented in the British Museum (Natural History) by a specimen of *H. asterias*. Hampson (1896 p.968) stated that the type of *C. demissalis* was in the British Museum (Natural History) and that Walker's description did not agree with his supposed type. And Hampson considered *C. demissalis* to be a subjective synonym of *asterias*. The type of *C. demissalis* has not been seen at the British Museum (Natural History) since the time of Walker's original description (Whalley, personal communication).

Hednota hagnodes (Turner)

Fig.8A

Talis hagnodes Turner, 1942, Proc. Roy. Soc. Qd 53: 83.
Hednota hagnodes Turner, Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 315.

Types.—Turner gave the type-locality and comments "Albany in February; Denmark in March; five specimens received from Mr. W. B. Barnard. Type in Queensland Museum." The holotype (T.6341), a male, is in the Queensland Museum and has label data "Denmark, W.A., 13-3-26, W. B. Barnard" (J. T. Woods, personal communication).

Diagnosis.—Forewing has a subrectangular apex, is pale brownish ochreous, and has some sparsely scattered fuscous (Fig.8A).

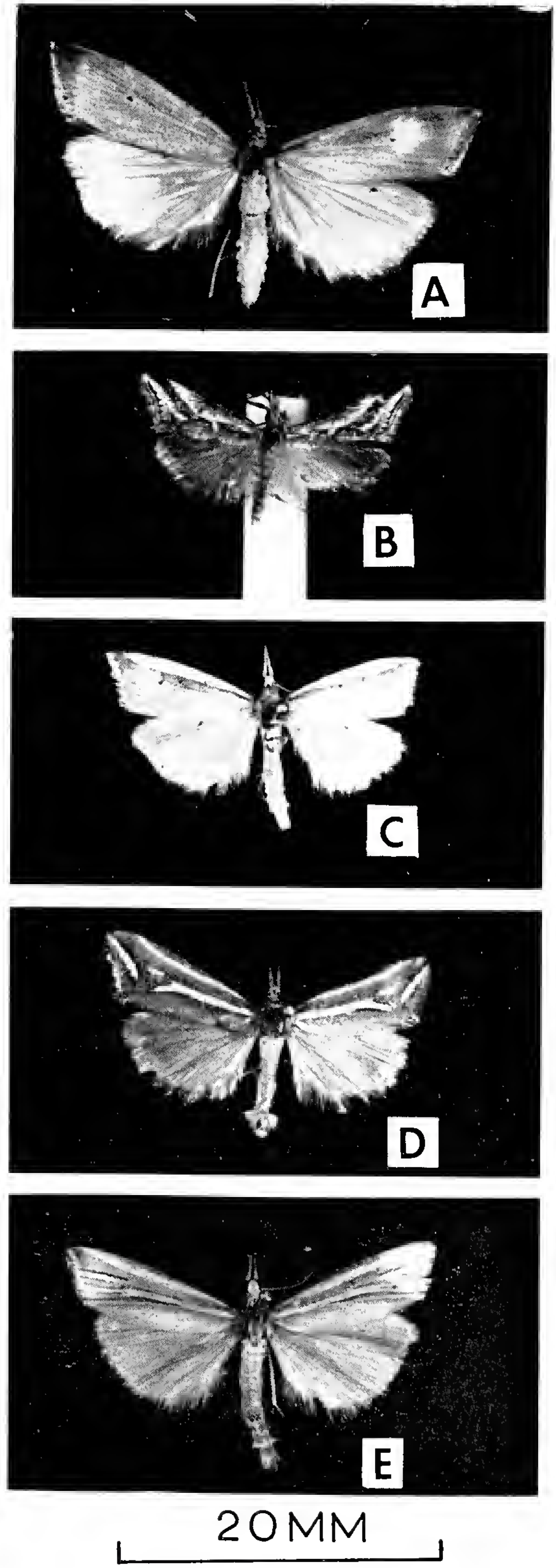

Figure 8 (next column).—A, *H. hagnodes*, male, Denmark, W.A.; B, *H. milvella*, male, Albany, W.A.; C, *H. peripeuces*, male, Albany, W.A.; D, *H. hoplitella*, male, Albany, W.A.; E. *H. relatalis*, male, Denmark, W.A.

Specimens examined.—8 ♂, 1 ♀.

Western Australia: Albany, 15.ii.1926, WBB, 1 ♂ ANIC; 8.iii.1926, WBB, 1 ♂ ANIC. Denmark, 9.iii.1926, WBB, 1 ♂ QM; 12.iii.1926, WBB, 1 ♂ QM; 13.iii.1926, 2 ♂ ANIC; 13.iii.1926, WBB, 1 ♂ QM; 16.iii.1926, WBB, 1 ♂ ANIC., Nedlands, 5.iv.1962, MMHW, 1 ♀ ANIC.

Comments.—This speeies ean be distinguished from *H. vetustella* by the eolour of the forewing and the shape of its apex.

Hednota milvella (Meyriek)

Fig.8B

Crambus milvellus Meyrick, 1879, Proc. Linn. Soc. N.S.W. 3: 181.

Talis milvellus (Meyrick). Hampson, 1896, Proc. Zool Soc. Lond. **1895**: 967.

Talis milvella (Meyrick). Turner, 1904, Proc. Roy. Soc. Qd **18**: 172.

Hednota milvellus (Meyrick). Bleszynski and Collins, 1962, Acta Zool. Cracov. **7**: 316.

Types.—Deseribed by Meyriek from one male, and the type-loeality and eomments were "near Sydney, in Mareh". The holotype (label data "Sydney N.S. Wales 22/3/78") is in the British Museum (Natural History) (Whalley, personal eommunieation).

Diagnosis.—This is a very distinet speeies; it is the smallest (expanse 13.0 mm) of all the Western Australian *Hednota*. The forewing is dark fuseous, espeeially towards the apex, whieh is strongly produeed. The rather broad white streak from base to middle of dise, there deflexed upwards and running to eosta just beyond two-thirds, and the white streak from three-fourths of fold to apex, are eharaeteristie of this speeies (Fig. 8B).

Specimens examined.—3 ♂.

Western Australia: Albany, 23.iii.1926, WBB, 3 ♂ QM.

Figure 10.—Portion of antenna of male of: A, *H. peripeuces*, Nedlands, W.A.; B, *H. relatalis*, Koojan, W.A.; C, *H. koojanensis*, sp. nov., Koojan, W.A.; D, *H. empheres*, sp. nov., Nedlands, W.A.

Hednota peripeuces (Turner)

Figs.8C; 10A; 11A,B,C; 12A

Talis peripeuces Turner, 1942, Proc. Roy. Soc. Qd 53: 84.

Hednota peripeuces (Turner). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 316.

Types.—Turner gave the type-loeality and eomments "Albany in Mareh; six speeimens reeeived from Mr. W. B. Barnard. Type in Queensland Museum". I have disseeted the genitalia (Slide no. T.6343a) of the holotype (T.6343), a male, labelled "Albany, W.A., 1-3-26, W. B. Barnard", in the Queensland Museum.

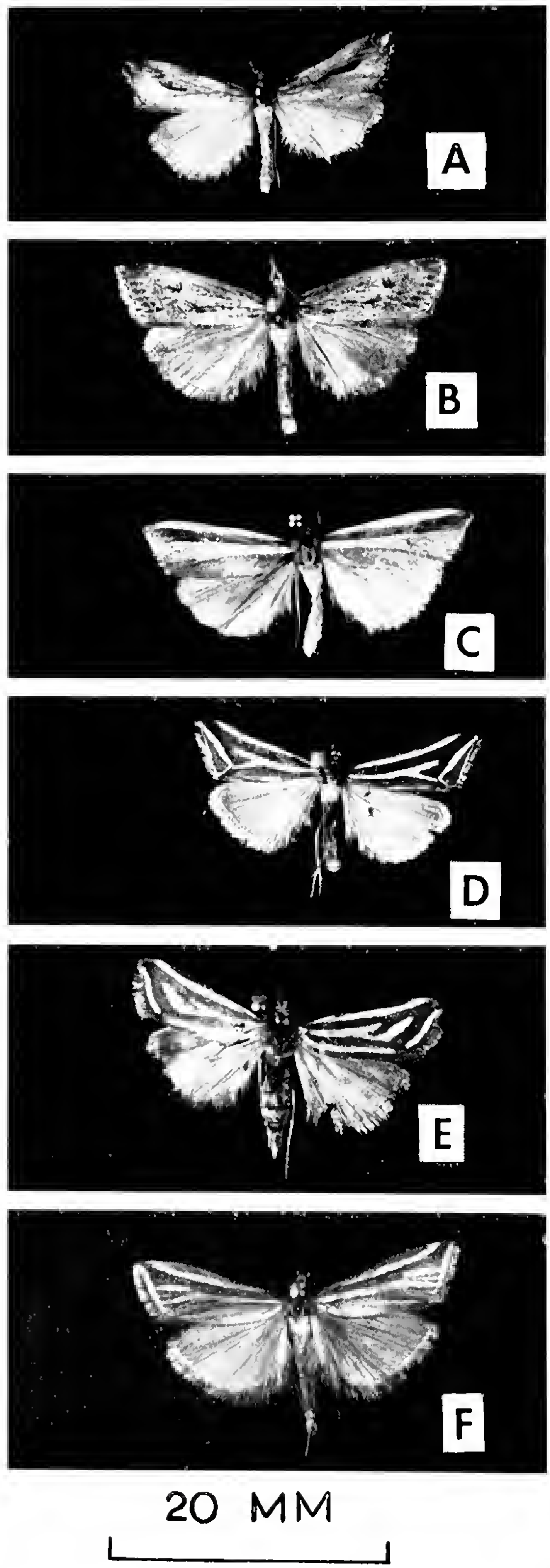

Figure 9 (next column).—A, *H. cotylophora*, male, Denmark, W.A.; B, *H. ancylosticha*, sp. nov. (holotype), male, Koojan, W.A.; D, *H. tenuilineata*, sp. nov. (holotype), male, Kojonup, W.A.; E, *H. odontoides*, sp. nov. (holotype), female, Nedlands, W.A.; F, *H. empheres*, sp. nov. (holotype), male, Nedlands, W.A.

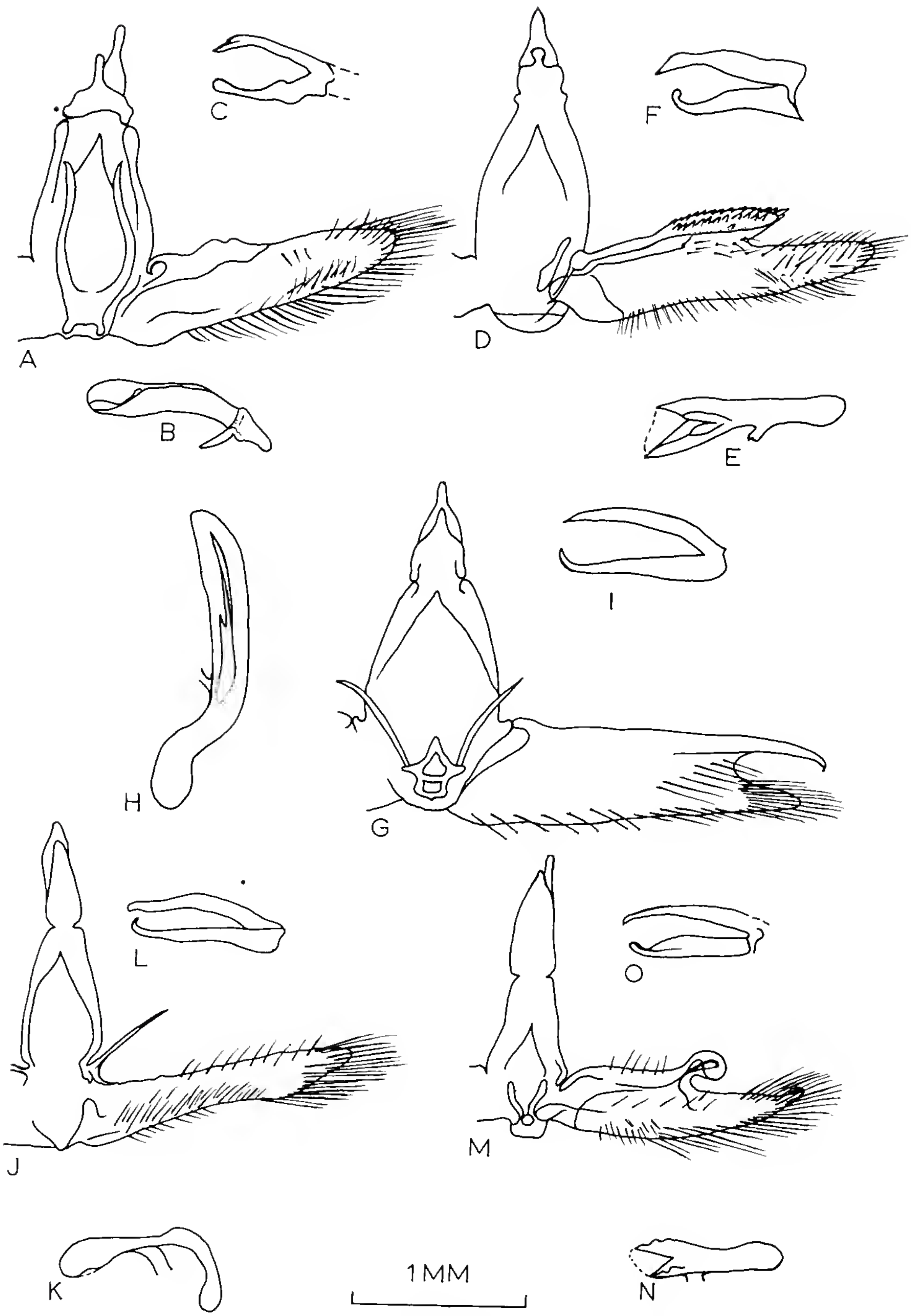

Figure 11.—Male genitalia of: A, B, C, *H. peripeuces*. Nedlands, W.A.; J, K, L, *H. koojanensis*, sp. nov., Koojan, W.A.; M, N, O, *H. empheres*, sp. nov., Koojan, W.A.

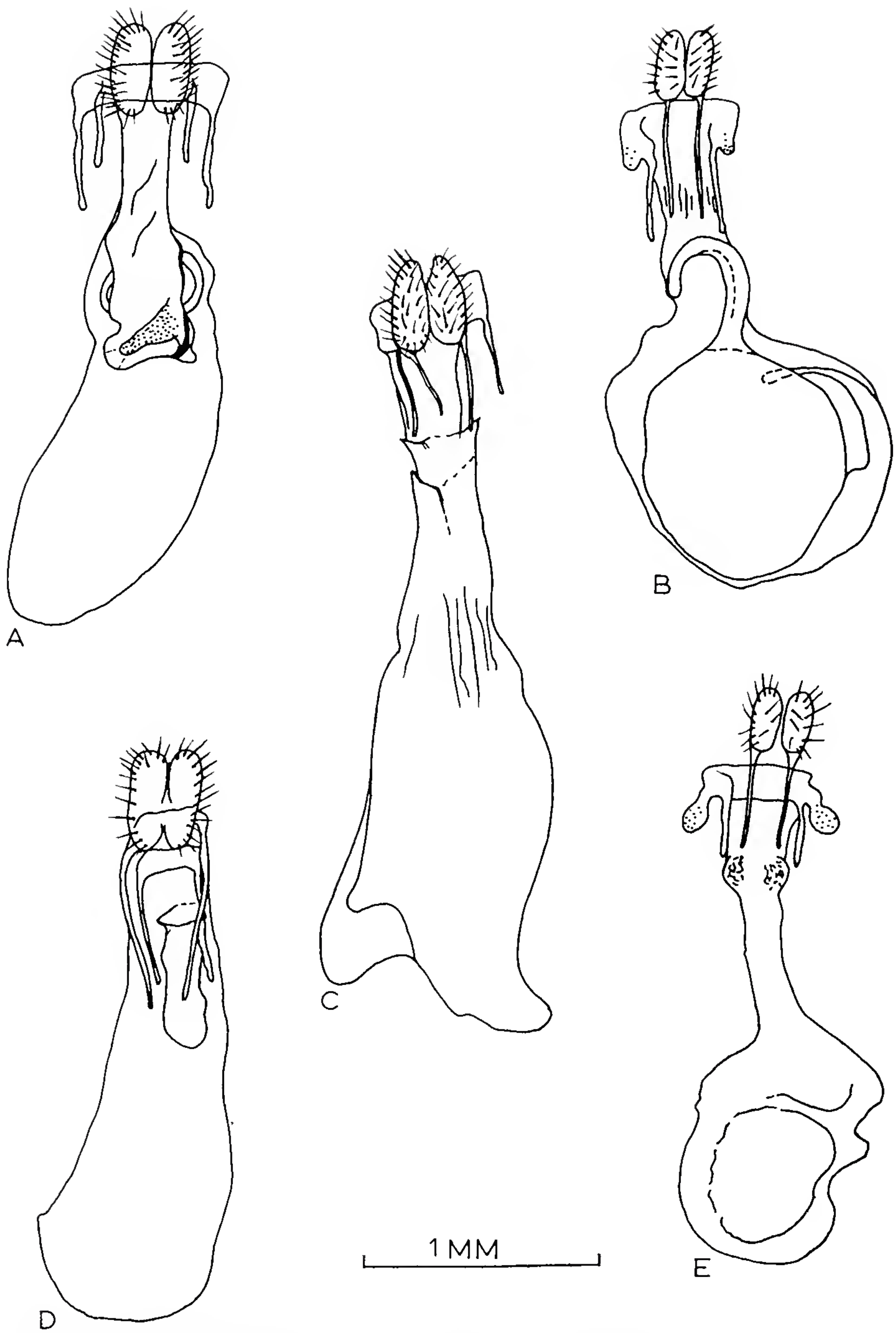

Figure 12.—Female genitalia of: A, *H. peripeuces*, Kojonup, W.A.; B, *H. ancylosticha*, sp. nov., Kojonup, W.A.; D, *H. koojanensis*, sp. nov., Koojan, W.A.; E, *H. empheres*, sp. nov., Koojan, W.A.

Diagnosis.—Can be distinguished by the forewing which is brownish grey partly suffused with white and partly sprinkled with fuscous; and has a white subcostal streak, from base to near apex, pale ochreous brown on costal side and with a dark fuscous line on lower edge; a distinct blackish dot in disc at two-thirds; and dorsal area of white with fuscous irroration and some pale ochreous streaks on veins (Fig.8C). Male antennae with long narrow teeth wide apart (Fig.10A).

Male genitalia (Fig.11A,B,C).—Uncus and gnathos elongated towards rounded apex; anellar arms outwardly curved and pointed at apex; costa of valva wavy and curled inwards at base; aedoeagus rounded at apex.

Female genitalia (Fig.12A).—Corpus bursae elongate, rounded at bottom; ductus bursae heavily sclerotized at bottom towards corpus bursae.

Specimens examined.—17♂, 4♀.

Western Australia: Albany, 1.iii.1926, WBB, 4♂ (including holotype of *Talis peripeuees*) QM; 2.iii.1926, WBB, 4♂ ANIC; 2.iii.1926, WBB, 1♂ QM. Kojonup, 24.iii.1962, MMHW, 1♂ WAM; 12.iii.1963, ALR, 1♂ 1♀ WAC. Nedlands, 12.iii.1963, MMHW, 1♀ ANIC; 18.iii.1963, MMHW, 1♂ WAC; 28.iii.1963, MMHW, 1♂ WAC; 2.iv.1963, MMHW, 1♀ WAC; 5.iv.1963, MMHW, 2♂ WAC; 28.iv.1963, MMHW, 1♂ WAC; 15.iv.1964, MMHW, 1♂ WAC. Wanneroo,, 15.iv.1963, GSMC, 1♀ WAC.

Comments.—Said by Turner (1942) to be nearest to *invalidella* [a Tasmanian species].

Hednota hoplitella (Meyrick)
Fig.8D

Crambus hoplitellus Meyrick, 1879, Proc. Linn. Soc. N.S.W. 3: 188.
Talis hoplitellus (Meyrick). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 969.
Talis hoplitella (Meyrick). Turner, 1904, Proc. Roy. Soc. Qd 18: 172.
Hednota hoplitellus (Meyrick). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 315.

Types.—Meyrick described the species from an unspecified number of specimens of both sexes, and gave the type-locality and comments "A very distinct species; abundant in a very restricted locality near Sydney, in March." A series of syntypes (seven males, one female) is in the British Museum (Natural History) (Whalley, personal communication). Following Whalley's selection, I hereby designate as lectotype of *Crambus hoplitellus* Meyrick one of the above specimens, a male labelled "24/3/78 Sydney, N.S.Wales; Meyrick coll.".

Diagnosis.—This species can be distinguished by the deep brownish ochreous forewing which is partially suffused with darker brown, and particularly by the central silvery white streak. This streak, which is strongly blackish-margined, commences at base and gradually dilates to beyond middle, where it abruptly bifurcates. Both these branches are short and reach three-fourths disc. The upper branch is slender, and abruptly swollen towards apex beneath. The lower branch is short and pointed. Around the apex of each branch is an irregular cloud of mainly black; from between these clouds proceeds a silvery white, above strongly black-margined, broad streak obliquely upwards to apex (Fig.8D). There is also a straight narrow silvery white subcostal streak, enclosing a narrow fuscous costal streak. Male antennae are strongly bipectinate.

Specimens examined.—11♂, 4♀:

Western Australia: Albany, 11.ii.1926, WBB, 1♂ ANIC; 2.iii.1926, WBB, 1♀ ANIC; 2.iii.1926, WBB, 1♂ QM; 26.iii.1926, WBB, 1♂ ANIC; 26.iii.1926, WBB, 2♂ QM. Kojonup, 7.iv.1963, ALR, 1♂ WAC. Koojan, 3.iv.1962, LEK, 1♀ WAM; 29.iii.1963, LEK, 1♀ WAM. Nedlands, 2.iv.1959, MMHW, 1♀ WAC; 10.iv.1961, MMHW, 1♂ ANIC; 4.iv.1963, MMHW, 1♂ WAC; 9.iv.1964, MMHW, 1♂ WAC; 10.iv.1964, MMHW, 1♂ WAC. Wanneroo, 3.iv.1962, GSMC, 1♂ ANIC.

Hednota relatalis (Walker)
Figs.8E; 10B; 11D,E,F; 12B

Crambus relatalis Walker, 1863, List Lep. Ins. Coll. Brit. Mus. 27: 172, 173.
?*Crambus argyroneurus* Zeller, 1863, Chil. Cramb. Gen. Spec.: 47.
Crambus relatalis Walker. Meyrick, 1897, Proc. Linn. Soc. N.S.W. 3: 191, 192.
Talis relatalis (Walker). Hampson, 1896, Proc. Zool. Soc. Lond. 1895: 969.
Talis relatalis (Walker). Turner, 1904, Proc. Roy. Soc. Qd 18: 173.
Prosmixis radialis Hampson, 1919, Ann. Mag. Nat. Hist. (9) 4: 147.
?*Talis diargyra* Turner, 1925, Trans, Roy. Soc. S. Aust. 49: 42.
Hednota relatalis (Walker). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 317.

Types.—Walker described *C. relatalis* from specimens from "a Adelaide. From Mr. Wilson's collection. b. Tasmania. Presented by M. Allport, Esq." Following Whalley's selection, I hereby designate as lectotype of *Crambus relatalis* Walker a male specimen, in the British Museum (Natural History), labelled "*relatalis*, Adelaide, S. Aust. 52/9 ,Pyralidae, Brit. Mus. Slide No. 7030, ♂". This specimen was labelled by Walker (Whalley, personal communication). The holotype of *C. argyroneurus,* a male, with type-locality Adelaide (additional label data "Mann. Abgeb 857; M. Berol; slide No. 4153 S. Bleszynski"), is in Vienna, according to Bleszynski (Whalley, personal communication). I have not seen the description by Zeller, but Hampson (1896 p.969) regarded *C. argyroneurus* as a synonym of *relatalis*. *P. radialis* was described by Hampson, who gave the type-locality and comments "W. Australia, Waroona *(Berthond)*, 1♂ type. *Exp.* 30mm." The holotype (label data "Waroona, W.A. 14.III.1908 G. F. Berthoud. 1910-194; B.M. Pyralidae Slide No. 7110") is in the British Museum (Natural History) (Whalley, personal communication). The description of *P. radialis* fits *H. relatalis*. I have not seen the holotypes of *C. argyroneurus* or *P. radialis,* and I quote *C. argyroneurus* as synonym following Bleszynski and Collins (1962 p.317). Whalley has compared a slide of mine of male genitalia of *relatalis* with the type genitalia of *P. radialis* (Pyralidae Slide No.7110) and states, personal communication, that they agree exactly and that both the above slides also agree exactly with the genitalia slide (No. 7030) of the *relatalis* lectotype.

T. diargyra is externally very similar to *relatalis* and has been listed as a synonym of it by Bleszynski and Collins (1962). I have examined the holotype of *T. diargyra,* a female, labelled "Swan R. J. S. Clark", in the Australian National Insect Collection; and have dissected its genitalia (Slide No.P250). I here treat *diargyra* as a possible synonym only; more females of *relatalis* need to be examined for variability of genitalia before the status of *diargyra* is ascertained.

Diagnosis.—This species can be distinguished by the gilded forewing which has a silvery white subcostal streak and a silvery white slightly blackish-bordered main discal streak that is divided into three long exterior streaks, which are connected by an almost marginal white streak (Fig.8E). Of the three long exterior streaks, the one nearest to costa is better defined and broader that the other two and separated from the main streak basally; the other two long exterior streaks are close together, nearly parallel, and proceed to termen costal to the tornus. Male antennae are strongly pectinate with much fine hair on teeth (Fig.10B).

Male genitalia (Fig.11D,E,F).—Uncus broad, forming an abrupt point; gnathos dilate, rounded at apex; valva with thick costa and well-developed thorny ampulla; aedoeagus wide at apex and with an invagination.

Female genitalia (Fig.12B).—Corpus bursae enlarged, rounded and with rounded sclerotization which has two curved arms; ostium bursae region wide, somewhat sclerotized; slightly bulbous lobes near bases of apophyses anteriores.

Specimens examined.—20 ♂, 6 ♀.

Western Australia: Beverley, 5.iv.1962, PJL, 1♀ WADA. Denmark, 17.iii.1926, WBB, 1♂ QM; 21.iii.1926, WBB, 1♀ QM; 22.iii.1926, WBB 1♂ QM. Kojonup, 24.iii.1960, JDB, 1♂ ANIC; 2.iv.1960, JDB, 1♂ ANIC; 19.iii.1961, MMHW, 1♂ WAM; 17.iii.1961, RJP, 1♂ ANIC; 22.iii.1961, MMHW, 1♂ 1♀ WAM; 25.iii.1961, MMHW, 1♂ WAM; 1.iv.1961, MMHW, 3♂ WAM; 20.iii.1962, ALR, 1♂ ANIC; 13.iii.1962, ALR, 1♂ ANIC; 15.iii.1963, MMHW, 1♂ WAM; 23.iii.1963, ALR, 1♀ WAC; 30.iii.1963, ALR, 1♂ WAC; 17.iii.1964, ALR, 1♂ WAC; 19.iii.1964, ALR, 1♂ WAC; 20.iii.1964, ALR, 1♂ WAC. Koojan, 1961, LEK, 1♂ WAM; 6.iv.1962, LEK, 1♀ WAM; 28.iii.1963, LEK, 1♂ WAM. Swan R., J.S. Clark, 1♀ (holotype of *Talis diargyra*) ANIC.

Hednota icelomorpha Turner

No figure available—see comments

Talis icelomorpha Turner, 1905, Proc. Roy. Soc. Qd 19: 65.
Hednota icelomorpha (Turner). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 315.

Types.—The type, a female, from Bridegtown (Western Australia), was lodged in the Lyell Collection. The holotype has label data "G. Lyell Coll. Pres. 31-7-32; Bridgetown, Apl. 1905; Type-3592" and is in the National Museum of Victoria (A. Neboiss, personal communication).

Diagnosis.—Unlike the other Western Australian *Hednota*, this species is said to have a forewing with a fine indistinct median whitish streak from base to three-fourths, margined above with fuscous, and a dark fuscous discal dot on lower edge of median streak shortly before end.

Comments.—Turner states that *icelomorpha* is near *H. acontophora* [which does not occur in W.A.] but "frons with a longer cone, forewings with termen not sinuate, central streak not prolonged to termen or apex, cilia without darker line". Unfortunately, I have been unable to see the holotype of *icelomorpha*. I have not seen a single specimen fitting the description of *icelomorpha* among the collections examined and among the Western Australian light trap material. But I have examined many specimens of *H. acontophora* (Meyrick) from the Eastern States.

Hednota cotylophora (Turner)

Fig.9A

Talis cotylophora Turner, 1942, Proc. Roy. Soc. Qd 53: 83.
Hednota cotylophora (Turner). Bleszynski and Collins, 1962, Acta Zool. Cracov. 7: 314.

Types.—When describing the species, Turner said that he received, from Mr. W. B. Barnard, six specimens collected in March and April at Denmark (Western Australia). The holotype (T.6341) a male, is in the Queensland Museum and has label data "Denmark, W.A., 3-4-26, W. B. Barnard" (J. T. Woods, personal communication).

Diagnosis.—Forewing brownish grey; with a slender white curved median line from one-third to two-thirds, its concavity on costal side filled with fuscous; a fuscous costal streak from base to three-fifths; a very slender white subterminal line inwardly oblique from costa before apex, soon curved outwards and sinuate to tornus; white apical spot preceded by a fuscous costal spot; and blackish spots, usually three, on termen towards tornus (Fig. 9A).

Specimens examined.—6 ♂, 1 ♀.

Western Australia: Denmark, 16.iii.1926, WBB, 1♂ ANIC; 22.iii.1926, WBB, 3♂ QM; 28.iii.1926, WBB, 1♂ ANIC; 2.iv.1926, WBB, 1♀ ANIC; 3.iv.1926, WBB, 1♂ ANIC.

Comments.—At a glance, this species looks like a rubbed *H. dichospila*. But it is a distinct species; e.g. the male antennae are not bipectinate as in *H. dichospila* but are pectinate and have wider and much stronger teeth with the apices of the teeth densely hairy. On forewing-markings *H. cotylophora* can be distinguished from *H. dichospila* by the lack of the transverse mark in disc at one-third; in that the slender white curved median line (its concavity on costal side filled with fuscous) extends further towards base than the corresponding one in *H. dichospila* and is not as curved upwards towards apex; and by the lack of the pair of distinct white spots on termen above tornus.

Hednota ancylosticha, sp. nov.

Figs.9B; 11G,H,I; 12C

Types.—The holotype is an adult male with wing expanse 23.9 mm (Fig. 9B) and label data "Nedlands, W.A., Light Trap, 21 Mar. 1961, M. M. H. Wallace" (Genitalia Slide No. P248), in the Australian National Insect Collection. Forty-four paratypes; for details see specimens examined.

Description.—Head whitish. Labial palpi twice as long as head, whitish on dorsal aspect, dark fuscous on sides, ventral aspect whitish mixed with dark fuscous. Antennae whitish ochreous, in both male and female very much as in *H. longipalpella*. Thorax fuscous ochreous. Abdomen whitish. Legs ochreous white. Forewing elongate, rather dilate, costa straight, termen subdentate, slightly rounded; ochreous, fuscous, and suffused with white centrally and towards dorsum; whitest on disc, which irregularly has much ochreous and some fuscous; towards base the colour becomes more ochreous and white, and there is a short distinct white median streak from base; a violet-silvery transverse metallic line which has a portion missing

in the middle (which is white), sharply angulate above and below middle, upper angulation much fainter than the one below; a somewhat rounded violet-silvery metallic mark at about two-thirds disc, convex towards base and strongly margined on internal (convex) side with black; behind this is an irregular sprinkling of fuscous; then corresponding to the silvery metallic outwardly-curved subterminal line of *H. longipalpella* there is a curved series of six separate silvery metallic patches which are rounded towards base but towards termen merge into six elongate rod-like patches of fuscous; the silvery metallic patches are margined with fuscous internally, and the patch closest to costa merges into an inwardly curved white subterminal line reaching costa; costal region near apex dark fuscous; termen with seven black spots on extremities of veins, the spot second closest to dorsum is elongated towards base; cilia silvery metallic fuscous grey with a whitish line at base and in middle. Hindwing pale fuscous grey; cilia white with a fuscous grey parting-line.

Male genitalia (Fig.11G,H,I).—Uncus elongated towards rounded apex; gnathos arms meeting abruptly; anellar arms shortish, curved outwardly and tapering to a fine point; anellus with a point towards gnathos; valva with costa nearly straight, then downcurved at apex to form a point, apex then has inward arch which proceeds outwards to form a second more-rounded point of apex, dorsum slightly wavy; aedoeagus large, curved, with concave aspect on side of ductus ejaculatorius; cornutus as two, pointed horns differing in size, both united at base.

Female genitalia (Fig.12C).—Corpus bursae elongate, irregularly shaped at bottom; somewhat sclerotized exteriorly at ductus bursae; ostium bursae region sclerotized, broader than deep, slightly pointed towards corpus bursae.

Expanse.—Male 21.0-25.2 mm, female 21.7-27.8 mm.

Specimens examined.—18♂, 27♀.

Western Australia: Nedlands, 21.iii.1961, MMHW, 1♂ (holotype of *Hednota ancylosticha*, sp. nov.) ANIC. And the following paratypes—Albany, 21.ii.1926, WBB, 3♀ QM; 2.iii.1926, WBB, 1♂ 1♀ QM; 3.iii.1926, WBB, 1♀ ANIC; 8.iii.1926, WBB, 1♂ QM; 10.iii.1926, WBB, 1♂ QM; 15.iii.1926, WBB, 1♂ QM. Denmark, 9.iii.1926, WBB, 1♂ ANIC; 14.iii. 1926, WBB. 1♂ ANIC; 17.iii.1926, WBB, 2♀ ANIC. Kojonup, 15.iii.1961, MMHW, 1♀ WAM; 15.iii.1963, MMHW, 1♀ WAM; 15.iii.1963, MMHW, 1♀ WAM; 21.iii.1963, ALR, 1♂ 7♀ WAC. Nedlands, 29.iii.1959, MMHW, 1♀ WAC; 17.iii.1961, MMHW, 1♂ 1♀ ANIC; 27.iii.1961, MMHW, 1♂ ANIC; 10.iv.1961, MMHW, 1♀ ANIC; 18.iii.1963, MMHW, 2♀ WAC; 25.iii.1963, MMHW, 1♂ 1♀ WAC; 26.iii.1963, MMHW, 1♂ WAC; 27.iii.1963, MMHW, 1♂ WAC; 28.iii.1963, MMHW, 2♂ 1♀ WAC; 31.iii.1963, MMHW, 2♂ 1♀ WAC. Perth, Mathews, 1♂ 1♀ ANIC. Roleystone, 3.iv.1962, LEK, 1♀ WAM.

Comments.—Several specimens of this species stood in the collections above Turner's unpublished name *'ancylosticha'*, which I quicken for this species. The species is very close to *H. longipalpella* in wing markings, antennae, and genitalia of both sexes. Its forewing can be distinguished from that of *H. longipalpella* in that the middle portion of the violet-silvery metallic line is missing, and this line is more strongly angulate above and below middle than in *H. longipalpella;* also by the somewhat rounded violet-silvery metallic mark at about two-thirds disc, unlike the corresponding mark in *H. longipalpella* which is distinctly crescentic; and by the curved row of six prominent fuscous rod-like patches which are capped with silvery metallic patches placed as a broken subterminal line. Unlike *H. longipalpella,* it has no distinct ochreous white rings at the apices of the tarsal joints. In the male genitalia, the anellar arms and the anellus are different from those of *H. longipalpella;* and in the female genitalia, the lack of the elongate bottom of the corpus bursae and the lack of the elongate curved ribs along the length of the corpus bursae help to distinguish the species from *H. longipalpella*.

I have seen two specimens of this species from Blackwood, South Australia. Both were males with no further data, in the South Australian Museum. This is the only one of the new species, described in this paper, of which I have seen specimens taken from outside Western Australia.

Hednota koojanensis, sp. nov.

Figs.9C; 10C; 11J,K,L; 12D

Types.—The holotype is an adult male with wing expanse 21.4 mm (Fig. 9C) and label data "L. E. Koch, 24.iii.1961, Koojon, W. Aust., W.A.M. No. 63-441" (Genitalia Slide No. W.A.M. 63-441a), in the Western Australian Museum. Twenty-two paratypes; for details see speci- examined.

Description.—Head whitish ochreous. Labial palpi twice as long as head and ochreous fuscous, whitish ventrally except at apex, white ventrally behind eyes. Antennae whitish ochreous, male antennae with wide closely-set teeth (Fig. 10C). Thorax whitish ochreous. Abdomen whitish. Legs whitish grey, anterior pair fuscous whitish. Forewing narrowly triangular, apex acute, termen slightly sinuate, scarcely oblique; ochreous fuscous, partly suffused with white and suffused with some fuscous; a white subcostal streak from base to near apex, its costal edge pale ochreous fuscous; below this a wider ochreous dark fuscous streak diverging towards apex and termen, a still wider diverging white streak along length of wing, diverging to termen, sprinkled with some fuscous towards termen; rest of wing towards dorsum ochreous fuscous and with some fuscous spots towards termen; a pale ochreous subterminal line, separated by a narrow white streak from a pale ochreous submarginal line; a white terminal streak containing some triangular blackish dots more defined at tornus; cilia white. Hindwing whitish, termen slightly sinuate; cilia whitish.

Male genitalia (Fig.11J, K.L).—Uncus and gnathos both gradually tapering to rounded apex; gnathos sharply curved towards uncus internally at apex; anellar arms short and gradually tapering to a fine point; valva long and narrow, costa nearly straight, dorsum somewhat wavy; aedoeagus dilated and rounded at apex.

Female genitalia (Fig.12D).—Corpus bursae elongate, rounded at bottom; ductus bursae strongly scelerotized; apophyses long.

Expanse.—Male 19.4-23.8 mm, female 18.9-22.4 mm..

Specimens examined.—20♂, 3♀

Western Australia: Koojan, 24.iii.1961, 63-441, LEK, 1♂ (holotype of *Hednota koojanensis*, sp. nov.) WAM. And the following paratypes—Kojonup, 7.iii.1962, RJP, 1♀ ANIC; 16.iii.1962, MMHW, 1♂ WAM. Koojan, 22.iii.1961, LEK, 1♂ WAM; 24.iii.1961, LEK, 13♂ WAM; 24.iii.1961, LEK, 1♀ WAM; 26.iii.1961, LEK, 2♂ WAM; 1961, LEK, 2♂ WAM. Nedlands, 12.iv.1962, MMHW, 1♀ ANIC.

Comments.—On appearance of forewing this species is very close to *H. peripeuces*, but differs in having the wide ochreous dark fuscous streak diverging towards apex and termen, and the still wider white streak along length of wing and diverging to termen; also differs in the absence of the dark fuscous line at the base of the subcostal white streak from base to near apex; and, as a rule, in the absence of the distinct blackish dot in disc at two-thirds. The male antennae differ from those of *H. peripeuces* in that the teeth are wider, shorter and more closely-set (Figs. 10A and C). In the male genitalia, the differently shaped uncus, gnathos, anellar arms, and valvae distinguish *H. koojanensis* from *H. peripeuces*. In the female genitalia, *H. koojanensis* can be distinguished from *H. peripeuces* by the longer apophyses and the smaller and less complicated sclerotization in the ductus bursae region. The species has been found mostly at Koojan, W.A.

Hednota tenuilineata, sp. nov.

Fig.9D

Types.—The holotype is an adult male with wing expanse 20.3 mm (Fig. 9D) and label data "Kojonup, West. Aust., 28.III.60, J. D. Beresford", in the Australian National Insect Collection. Six paratypes; for details see specimens examined.

Description.—Head ochreous fuscous with a white line over each eye. Labial palpi twice as long as head, fuscous, whitish ventrally except at apex. Antennae dark fuscous, the male strongly bipectinate. Thorax ochreous fuscous. Abdomen pale ochreous fuscous. Legs pale ochreous fuscous, anterior pair more fuscous. Forewing moderately broad, termen almost straight; deep ochreous fuscous; a straight narrow silvery white subcostal streak proceeding from costa near base and ending on costa shortly before apex after curving upwards to meet it from about two-thirds of distance, enclosing a narrow deep ochreous fuscous streak; a silvery white, strongly fuscous-margined, central streak from base abruptly bifurcate beyond middle, both branches short, reaching to three-fourths disc; upper branch same width as before branching, bluntly pointed towards apex; lower branch same length as upper and gradually tapering to a point; from near point of lower branch proceeds a silvery white, above strongly black-margined, broad streak obliquely upwards to apex, sharp-pointed above, sending from its lower edge, which is slightly towards apex from point of lower branch, a distinct silvery white tapering streak sharply curved at a right angle pointing towards tornus and ending abruptly before tornus; apex of wing suffused with dark fuscous; three or four faint dark fuscous dots on hindmargin towards tornus; an indistinct line of dark fuscous along inner margin; a distinct, thin, white submarginal line along termen with a thin dark fuscous line along it exteriorly; cilia silvery metallic grey. Hindwing whitish grey, suffusedly darker grey along termen; cilia whitish with a fuscous grey parting-line.

Expanse.—Male 19.2-20.3 mm, female 19.8 mm.

Specimens examined.—5♂, 2♀.

Western Australia: Kojonup, 28.iii.1960, JDB, 1♂ (holotype of *Hednota tenuilineata*, sp. nov.) ANIC. And the following paratypes—Kojonup, 31.iii.1960, JDB, 1♀ ANIC; 17.iii.1961, RJP, 1♂ ANIC; 24.iii.1961, MMHW, 1♂ WAM; 16.iii.1963, ALR, 1♂ WAC; 5.iv.1963, ALR, 1♂ WAC. Nedlands, 13.iv.1964, MMHW, 1♀ WAC.

Comments.—Very close to *H. hoplitella* on forewing-markings, but distinguished from it by the lack of the clouds of black scales at the apices of the two branches; in that the oblique streak to apex is from near point of lower branch and is sharply curved at a right angle and pointing towards tornus; and in that all silvery white streaks are markedly thinner than those in *H. hoplitella*. The male antennae are like those of *H. empheres*, sp. nov. (Fig.10D).

Hednota odontoides, sp. nov.

Fig.9E

Types.—The holotype is an adult female with wing expanse 22.2 mm (Fig. 9E) and label data "Light Trap, Nedlands, 28.ii.61, M. M. H. Wallace", in the Australian National Insect Collection. Two paratypes; for details see specimens examined.

Description.—Head fuscous ochreous with a whitish line over each eye. Label palpi twice as long as head, fuscous, whitish internally and ventrally except at apex. Antennae dark fuscous, the male strongly pectinate with thick teeth. Thorax ochreous fuscous. Abdomen whitish. Legs fuscous whitish, anterior pair darker fuscous. Forewing moderately broad, termen slightly rounded; deep brownish ochreous, partly suffused with darker fuscous; a straight narrow silvery white subcostal streak, proceeding from costa near base, ending on costa again shortly before apex, and enclosing a narrow fuscous costal streak; a silvery white, faintly dark fuscous-margined, central streak from base, gradually dilating to near middle where it abruptly bifurcates, the upper branch short with upper edge straight and lower edge abruptly turning upwards to meet it forming a tooth-like point, lower branch thin for about length of upper branch and then forming a broad silvery white centrally dilated streak sloping obliquely towards apex and ending in a blunt point before apex in line with end of upper branch and costal edge of central streak; parallel to this sloping streak is a faintly dark fuscous-margined thin silvery white streak meeting termen before apex; an indistinct silvery white streak about as broad as subcostal streak along length of dorsum from base, enclosing a fuscous ochreous streak along dorsum; this silvery white streak ends indistinctly before meeting the thin silvery white streak that meets the termen; apex of wing suffused with dark fuscous; an irregular line of indistinct fuscous along termen; cilia silvery metallic grey with an

irregular darker grey line towards base. Hindwing whitish grey, suffusedly darker fuscous grey at apex; cilia whitish with a fuscous grey parting-line.

Expanse.—Male 24.2 mm, female 22.2-23.6 mm.

Specimens examined.—1♂, 2♀.

Western Australia: Nedlands, 28.ii.1961, MMHW, 1♀ (holotype of *Hednota odontoides*, sp. nov.) ANIC. And the following paratypes—Nedlands, 24.iii.1962, MMHW, 1♀ ANIC; 18.iii.1963, MMHW, 1♂ WAC.

Comments.—On the forewing-markings close to *H. hoplitella* and *H. tenuilineata*, but markedly distinguishable from them by the central streak having its upper branch tooth-like and its lower branch abruptly turned upwards forming a broad white centrally-dilated streak which slopes obliquely towards apex and ends in a blunt point before apex; and also by the silvery white streak near dorsum, and the silvery white streak meeting termen before apex. The male antennae are pectinate, unlike the strongly bipectinate antennae of *H. tenuilineata* and *H. empheres*, sp. nov.

Hednota empheres, sp. nov.
Figs.9F; 10D; 11M,N,O; 12E

Types.—The holotype is an adult male with wing expanse 23.1 mm (Fig.9F) and label data "Nedlands, W.A., Light Trap, 11 Apr. 1961, M. M. H. Wallace" (Genitalia Slide No. P249), in the Australian National Insect Collection. Six paratypes; for details see specimens examined.

Description.—Head ochreous with a white line over each eye. Labial palpi twice as long as head, dark fuscous, whitish internally and ventrally except at apex. Antennae dark fuscous; the male strongly bipectinate, apices of teeth dilate and upturned and with long hair (Fig.10D). Thorax fuscous ochreous. Abdomen whitish, slightly gilded. Legs whitish, anterior pair fuscous whitish. Forewing moderately broad, termen almost straight; ochreous, suffused with some fuscous, slightly gilded towards dorsum; a straight narrow silvery white subcostal streak, proceeding from costa near base, and ending on costa shortly before apex, enclosing a narrow ochreous streak suffused with some fuscous towards costal margin; a silvery white faintly dark fuscous-margined, central streak from base to disc, where it breaks up into three exterior streaks; the more costal of these streaks is better-defined and broader than the other two, dilated centrally, margined with fuscous, and separated from the main streak towards the base; the other two streaks are close together, nearly parallel, and proceed to termen costally to tornus; of these two streaks the one closer to the dorsum is less distinct than the other one; dorsum suffused with white from margin; a distinct broad silvery white submarginal streak with a strong dark fuscous-margined line externally; cilia greyish white with a pale fuscous parting-line. Hindwing slightly gilded, whitish grey; cilia whitish with a fuscous grey parting-line.

Male genitalia (Fig.11M,N,O).—Uncus narrowly tapering to rounded apex; gnathos abruptly tapering to rounded narrow apex; valva at apex narrow rounded and upturned, ampulla as a well-developed thin folded funnel; aedoeagus roughly dilate at apex and with an invagination.

Female genitalia (Fig.12E).—Corpus bursae irregularly rounded, some rounded internal sclerotization; ductus bursae long and narrow; bulbular sclerotization in ostium bursae region; bulbous lobes near bases of apophyses anteriores.

Expanse.—Male 23.1-24.2 mm, female 18.3-21.1 mm.

Specimens examined.—3♂, 4♀.

Western Australia: Nedlands, 11.iv.1961, MMHW, 1♂ (holotype of *Hednota empheres*, sp. nov.) ANIC. And the following paratypes—Koojan, 22.iii.1961, LEK, 2♀ WAM; 24.iii.1961, LEK, 1♂ WAM; 1961, LEK, 1♀ WAM; 14.iv.1962, LEK, 1♀ WAM. Nedlands, 11.iv.1961, MMHW, 1♂ ANIC.

Comments.—On forewing-markings closely resembling *H. relatalis*. But distinguishable by the exterior streaks being shorter and broader than in *H. relatalis*, and by the strong and broad submarginal silvery white streak, which in *H. relatalis* is narrower and only strong in apical half. Also the insect is not as strongly gilded as *H. relatalis*. The antennae of male *H. empheres* (Fig.10D), which are like those of *H. tenuilineata* but unlike those of *H. relatalis* (Fig.10B), can be distinguished from those of *H. panteucha* (Fig.5A) by the apices of the teeth being more upturned, dilate, and more hairy. The male genitalia of *H. empheres* and *H. relatalis* can be immediately distinguished by the ampullae, which have a funnel-shaped structure in the former and are thorny in the latter. In the female genitalia, the bulbous lobes near the apophyses anteriores are better developed

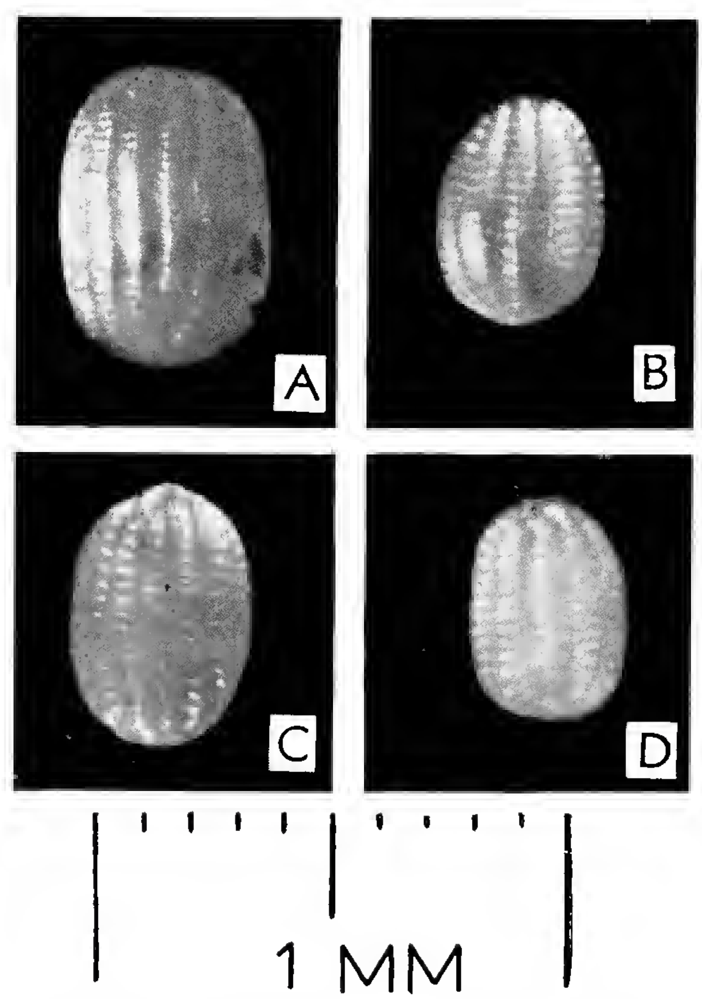

Figure 13.—The egg of: A, *H. panteucha*; B, *H. longipella*; C, *H. pedionoma*; D, *H. crypsichroa*.

in *H. empheres* than in *H. relatalis;* and *H. empheres* lacks the rounded sclerotization of the corpus bursae and the two curved arms which are present in *H. relatalis.*

Both *H. relatalis* and *H. empheres* have a faint, very narrow suggestion of a silvery white line, from central streak, commencing at one-third to half distance from base and proceeding towards tornus.

Immature stages of the four webworm species

The surfaces of the eggs of *H. panteucha, H. longipalpella, H. pedionoma* and *H. crypsichroa* have prominent longitudinal ribs and less prominent but more numerous transverse ribs giving the eggs a cross-hatched appearance. Photographs of the eggs of all four species are shown as Figure 13. The eggs are whitish when laid; and fertile eggs change colour after about half their developmental period has elapsed.

Table 2

Characteristics used to differentiate the immature stages of the four webworm species

Stage	Characteristic	Species			
		H. panteucha	*H. longipalpella*	*H. pedionoma*	*H. crypsichroa*
Egg. (Fig. 13)	Size	Mean length 0.68 mm. and diameter 0.47 mm. Larger (highly significant: $P<0.001$) than three species	Not significantly ($P>0.05$) different from each other; e.g., *H. longipalpella* had mean length 0.50 mm. and diameter 0.32 mm. [35 eggs of each of the four species were measured for these statistics, and the S.E. of the mean for length and diameter for each species was $\pm$ 0.01].		
	Colour during development	Orangish yellow	Bright red	Not red	Not bright red
	Transverse ribs	Not as pronounced or widely spaced as in *H. crypsichroa*			Very pronounced and widely spaced (even more evident than in Fig. 13D)
Larva	Mandible (Fig. 14)	No dorsal teeth, dorsal part of biting edge smooth and rounded	First two teeth prominent, dorsal teeth less well defined with teeth three and four tending to coalesce	Four well defined teeth, second one large. Dorsal edge rounded	Dorsal teeth ill-defined. Wide mandible with dorsal edge at a right angle to biting edge
Pupa	Fronto - clypeal "beak"	Prominent	Not prominent		
	Cremaster (Fig. 15)	Tri-lobed	Terminal two cremastral setae long, widely separated from each other	Terminal cremastral setae short, widely separated from each other	Terminal two cremastral setae short, narrowly separated from each other

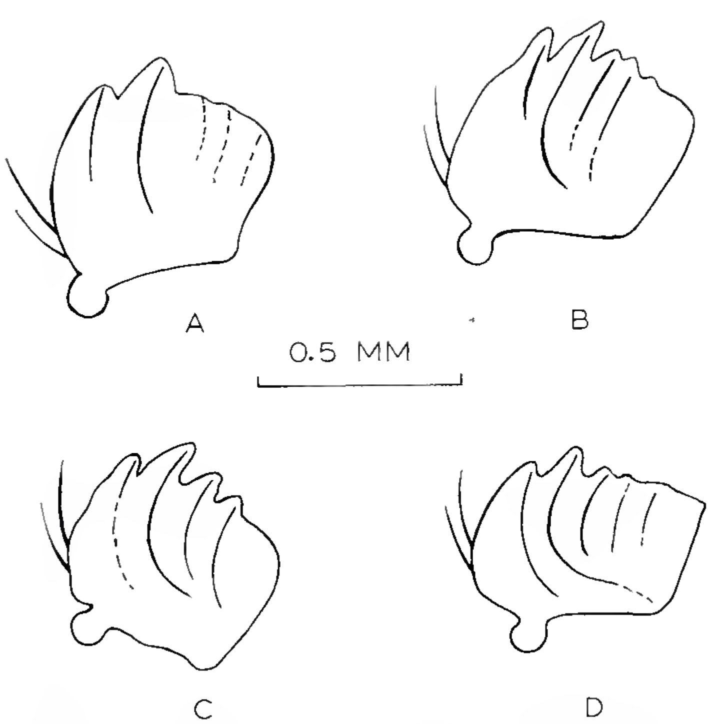

Figure 14.—Mesal view of right larval mandible of: A, *H. panteucha;* B, *H. longipalpella;* C, *H. pedionoma;* D, *H. crypsichroa.*

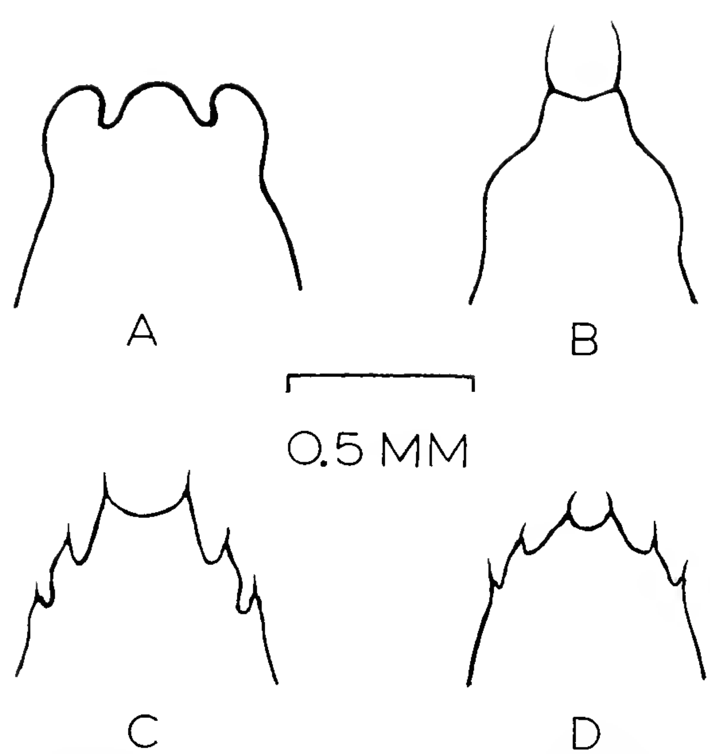

Figure 15.—Outline of ventral view of cremastral region of pupa of: A, *H. panteucha;* B, *H. longipalpella;* C, *H. pedionoma;* D, *H. crypsichroa.*

Larvae of the four species, although superficially alike, differ in details of body colouration and setal arrangement. However, specimens bred through their life cycles, and identified at the adult stage, revealed that the simplest method of distinguishing the late instar larvae, including aestivating larvae, of the four species was by the appearance of the biting edge of the mandible. In *H. panteucha,* the first two teeth, i.e. the most ventral ones, are large and wide with the second one noticeably longer than the first; the rest of the biting edge is smooth because the other teeth are extremely small. In *H. longipalpella,* the first two teeth are longer and more pointed, and the next two teeth tend to coalesce and they are followed (dorsally) by another small tooth. In *H. pedionoma,* the first four teeth are well-defined and deeply indented with the second tooth long, and the third slightly indented along its dorsal edge. In *H. crypsichroa,* the mandible is wide with the dorsal teeth ill-defined and the dorsal edge at about a right angle to the biting edge and not rounded where these edges meet. Mandibles of the four species are illustrated in Figure 14.

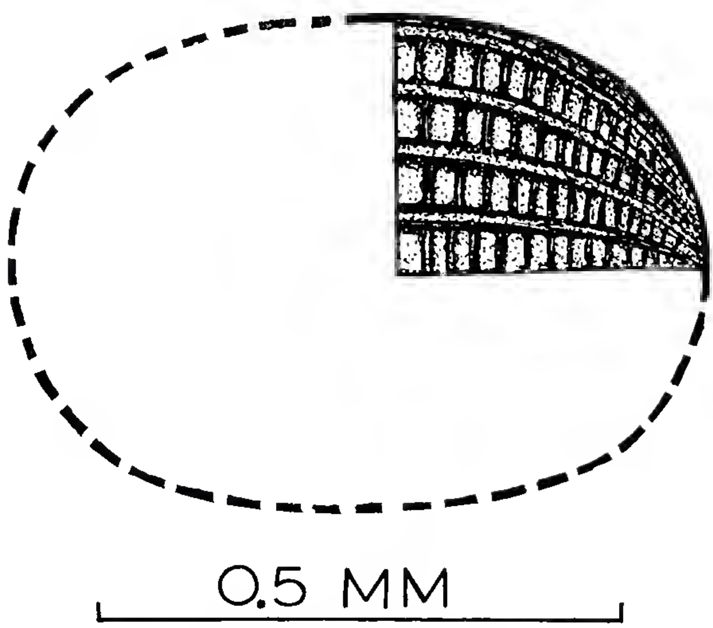

Figure 16.—Outline of egg of *H. panteucha* and portion showing appearance of surface.

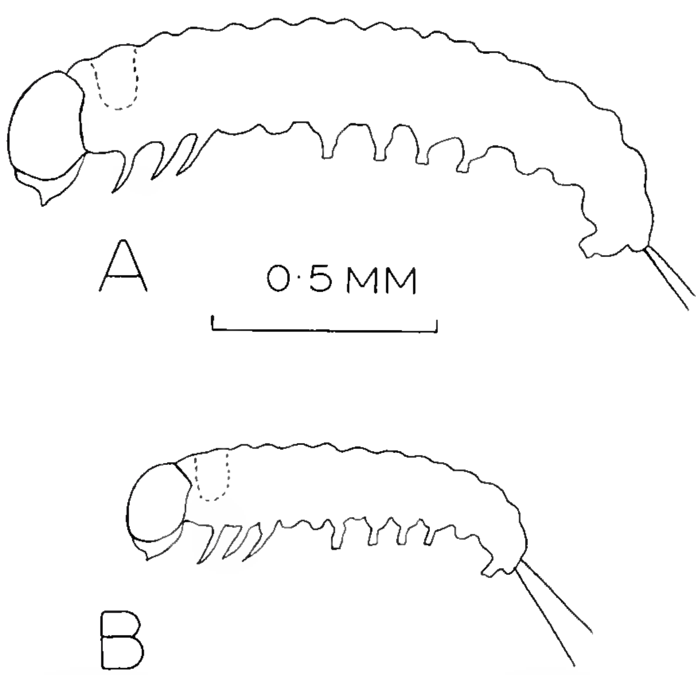

Figure 17.—Outline of first instar larva of: A, *H. panteucha;* B, *H. longipalpella.* Two setae on the tenth abdominal segment of each species indicate the difference in setal length relative to body length in the two species. (Dotted lines indicate prothoracic shields.)

The pupae of *H. longipalpella, H. pedionoma* and *H. crypsichroa* fall within the range of size and colour of pupae of *H. panteucha,* but they do not have its pronounced fronto-clypeal "beak". I found that each species has a different cremaster (Fig.15).

The characteristics which I employed to distinguish the four species during their immature stages are given in Table 2.

Immature stages of *H. panteucha*

Because the four webworm species could be distinguished during all stages in the life cycle, I was able to establish that only one of the species, *H panteucha* (except for one small patch, of about 2 yds. sq. during 1962 to 1963, of only *H. longipalpella*), lived in a paddock of barley grass at Koojcn. Thus it was possible for me to make a detailed biological and ecological study of *H. panteucha* in the paddock. Relative to *H. panteucha,* few moths of *H. pedionoma* and *H. crypsichroa* were observed there; extremely few of these were females and no oviposition by these two species was seen in the paddock. The larval and pupal stages of *H. pedicnoma* and *H. crypsichroa* were not found there during three years of observation. All moths bred from the area, except for the few *H. longipalpella* from the one small patch, were *H. panteucha.*

The outline and a portion of the surface appearance of the egg of *H. panteucha* are shown in Figure 16.

First instar larvae of *H. panteucha* and *H. longipalpella* are shown in outline in Figure 17. I differentiated first and later instar feeding larvae of these two species by the charactersitics show in Table 3.

Table 3
Characteristics used to differentiate the feeding *larvae of* H. panteucha *and* H. longipalpella

Stage	Characteristic	Species	
		H. panteucha	*H. longipalpella*
First instars (Fig. 17)	Body colour ..	Not red	Distinctly red
	Head size	Larger	Smaller
	Length of body setae	Shorter	Longer
Later feeding instars	Body pigmentation	Not reddish	Reddish
	Head colour	Lighter	Darker

Description of Final Instar Larva of *H. panteucha.*—Body length 18 mm, width 2.5 mm. Head width 1.8 mm. Head yellowish brown with dark brown markings. The part of fronto-clypeal apotome enclosed by the adfrontal sutures extends more than two-thirds of the distance to the vertical triangle. Two pale yellow bands dorsal of adfrontal sutures form an inverted V. Ocelli 3 and 4 smaller and closer together than other ocelli. The first two (ventral) teeth of the biting edge of the mandible are well defined; i.e., long and wide, particularly the second one. Other more dorsal teeth are practically non-existent, giving that part of the biting edge a smooth appearance ending dorsally in a distinct curve. The mesal view of the right mandible is shown in Figure 12A. Body cream to light brown with yellow to brown pigmented areas. (Feeding larvae appear greenish because of grass in the alimentary canal.) The prothoracic shield is darker than the other pigmented areas of the body. Crochets of abdominal prolegs arranged in complete circles; mainly biordinal, but partly triordinal. Spiracle of eighth abdominal segment of the same size as prothoracic spiracle; spiracle on seventh abdominal segment about half the size of that on the eighth abdominal segment; each of the other abdominal spiracles about half the size of that on the seventh abdominal segment. The general appearance of the larvae showing the pigmented areas and the setal arrangement is presented in Figure 18.

Number of Instars.—Under ideal conditions with adequate food, *H. panteucha* completed six larval instars. In laboratory experiments, larvae in which growth was prolonged by lack of food and low temperature, completed seven or eight instars. However, six instars was the usual number in the field. And this was determined for the area of detailed study by measuring the head capsules of several hundred larvae of *H. panteucha,* covering the whole range of head capsule size, and by making histograms of the frequencies of head capsule widths. At least fifty specimens of each instar were measured. Figure 19 shows the mean widths of the head capsules of the six larval instars, and the range of size within each instar. *H. longipalpella* in the area also had six instars.

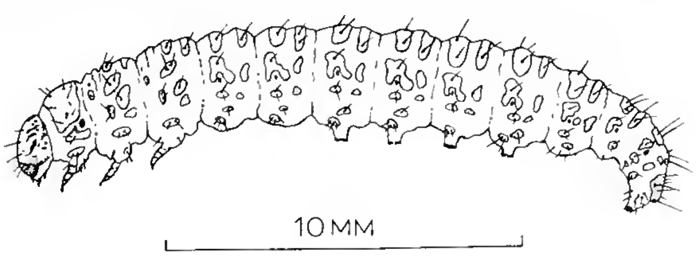

Figure 18.—Final instar larva of *H. panteucha.*

Pupae of *H. panteucha* (Fig.20) had the following dimensions: mean length 12.5 mm (range 9.0-14.0 mm), mean width 2.3 mm (range 2.0-3.0 mm). They are creamy yellow at first, soon turn honey-brown and remain so for most of their development, and then darken shortly before moth emergence.

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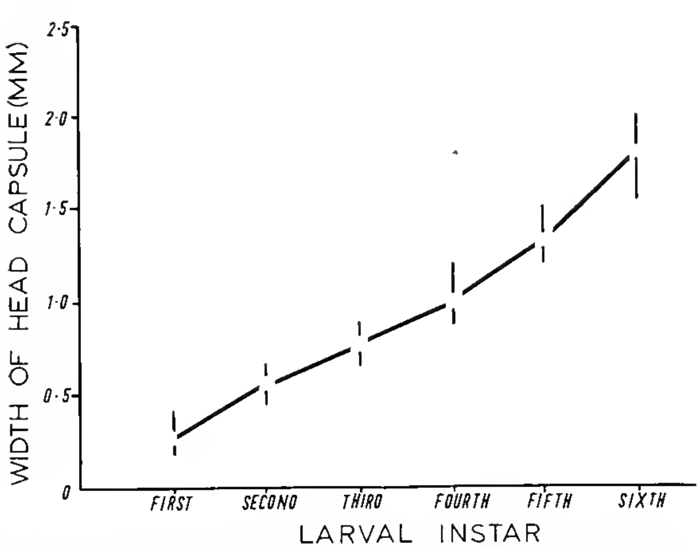

Figure 19.—Mean width of head capsule of each larval instar of *H. panteucha.* The vertical lines indicate the range of size within each instar.

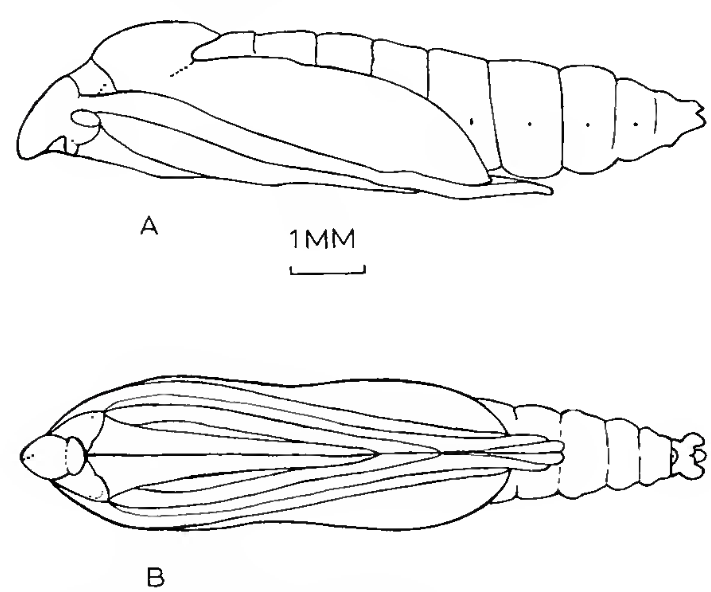

Figure 20.—Pupa of *H. panteucha:* A, lateral view; B, ventral view.

tralian Museum, Sydney; Mr. J. McNally and Mr. A. N. Burns, National Museum of Victoria, Melbourne; Dr. W. P. Crowcroft and Mr. G. F. Gross, South Australian Museum, Adelaide; Dr. A. R. Brimblecombe, Queensland Department of Agriculture and Stock, Brisbane; Mr. F. M. Read, Victorian Department of Agriculture, Melbourne; Mr. P. R. Birks, South Australian Department of Agriculture, Adelaide; Mr. C. F. H. Jenkins, Western Australian Department of Agriculture, South Perth; Miss Helen M. Brookes, Waite Agricultural Research Institute, Adelaide; and Mr. M. M. H. Wallace, Western Australian Regional Laboratory, C.S.I.R.O., Nedlands.

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14.—Some aspects of lateritisation in Western Australia

by P. L. C. Grubb*

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Abstract

Studies of two lateritic bauxite profiles near Jarrahdale in the Darling Ranges and a third 100 miles south of this near Greenbushes, Western Australia, show that although lithologically similar, there are differences in the distribution of their mineral components. The percentage variation with increasing height in each profile for kaolinite, halloysite, gibbsite, quartz, and goethite is relatively uniform. Boehmite, however, behaves rather more erratically, for although in both the Cobiac Pit near Jarrahdale and the Angus Cut near Greenbushes it shows a proportional increase in the earthy bauxite horizon, in the main Jarrahdale opencut, the boehmite is confined to the uppermost horizon of the hardcap. The chief factors accounting for the distribution of boehmite are considered to be physiography, water table fluctuations, and vegetation cover, this being supported by additional evidence from other bauxite deposits. Heavy mineral analyses suggest that lateritisation in the higher level Jarrahdale and Cobiac Pit sections was rather more intensive than in the lower level Angus Cut section near Greenbushes indicating that topography and tectonic history were rather more important than total rainfall during bauxitisation.

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Introduction

Bauxitic laterite in Western Australia, which is Tertiary in age, (Tomich 1964) forms a discontinuous surface horizon from 15 to over 40 feet thick in the Darling Ranges. This horizon increases in thickness and commercial grade from south to north over a distance of about 200 miles although its areal extent is apparently fortuitously defined by the present 25-inch isohyet.

The western boundary of this extensive Miocene laterite surface, where it adjoins the low flat Swan lowlands, is abruptly delineated by the extensive Darling Ranges thrust fault, movement along which, although initiated during the early Palaeozoic, has continued intermittently up to the present (McWhae *et al.* 1956). The laterite horizon shows extensive faulting and minor flexuring which David (1950) considers to be late Miocene and associated with epeirogenic uplift following peneplanation.

As a direct consequence of this tectonic activity, the extensive Tertiary laterite surfaces of Western Australia vary in elevation from 200 to 1,850 feet, although the higher grade gibbsitic bauxite is confined to elevations between 600 and 1,700 feet (Tomich 1964).

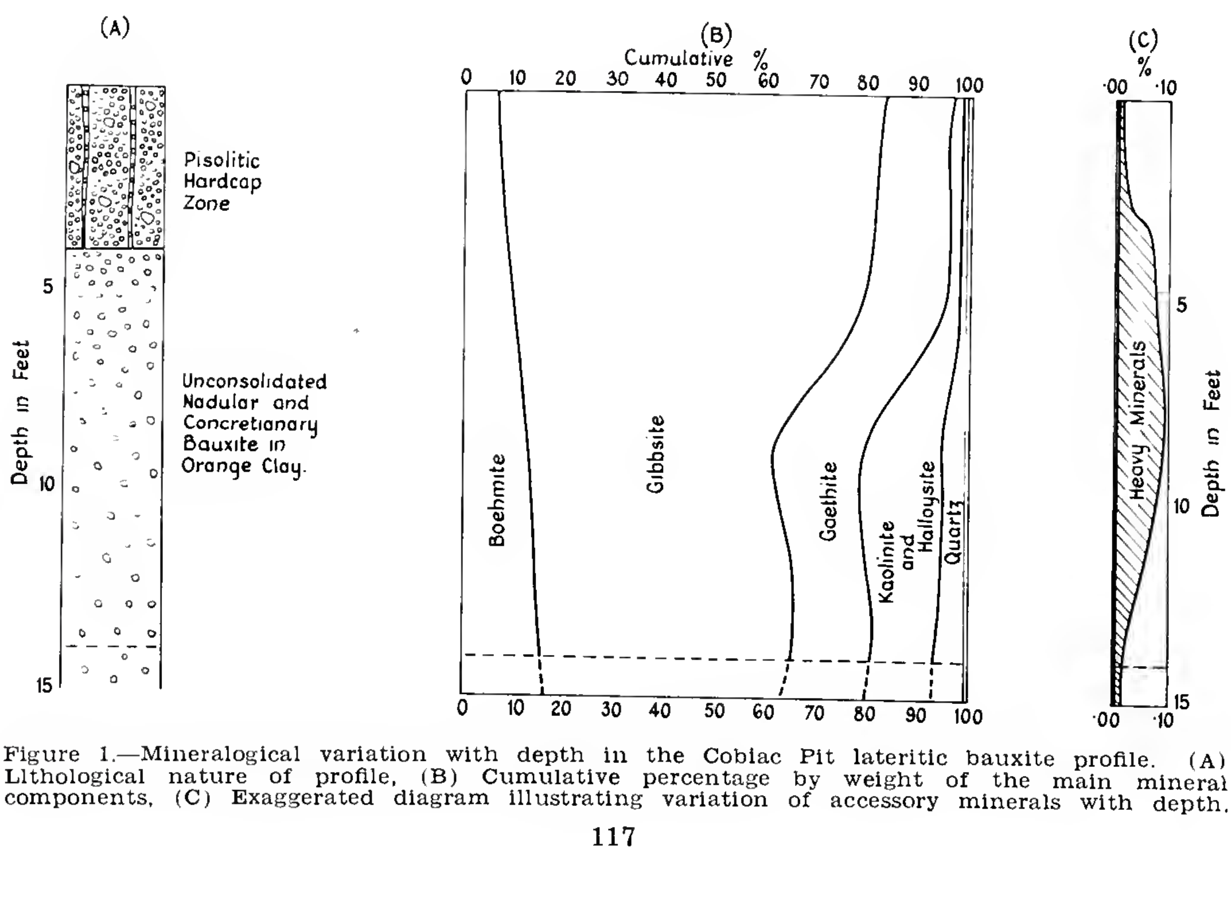

Figure 1.—Mineralogical variation with depth in the Cobiac Pit lateritic bauxite profile. (A) Lithological nature of profile, (B) Cumulative percentage by weight of the main mineral components, (C) Exaggerated diagram illustrating variation of accessory minerals with depth.

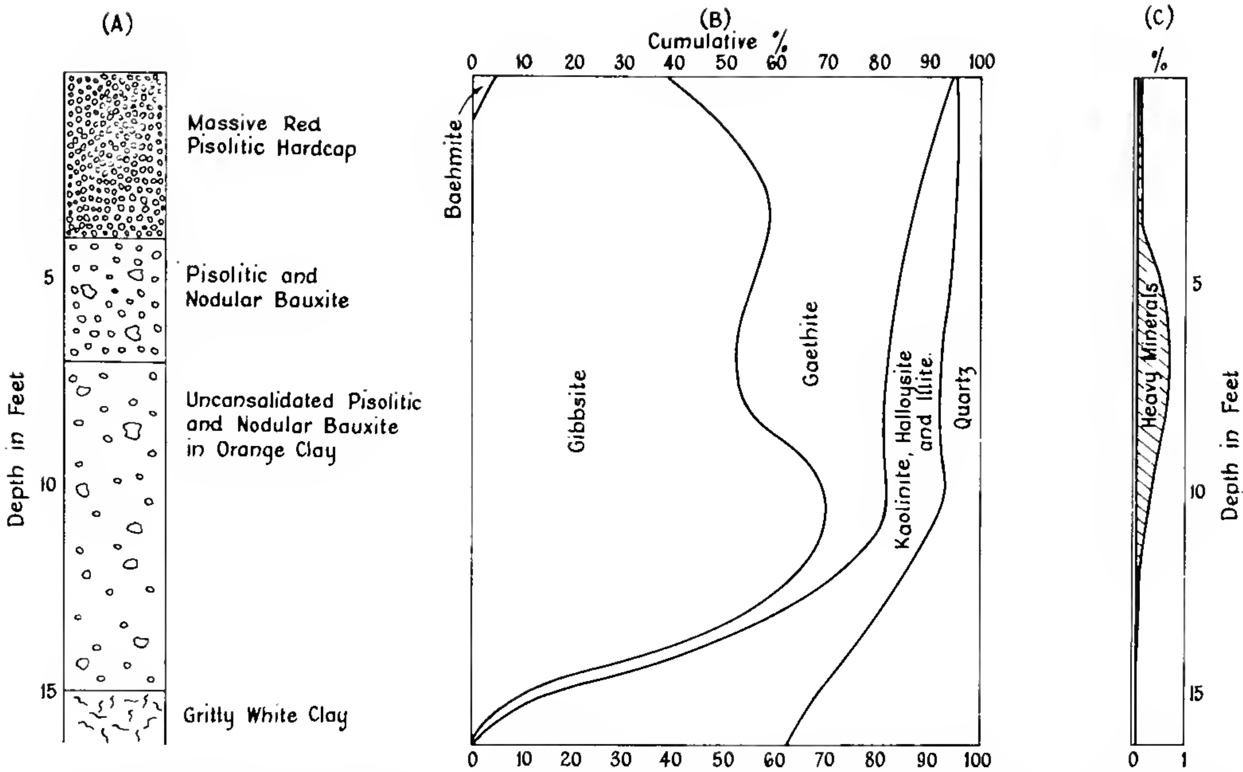

Figure 2.—Mineralogical variation with depth in the profile of the main Jarrahdale open-cut. (A) Lithological nature of profile, (B) Cumulative percentage by weight of the main mineral components, (C) Exaggerated diagram illustrating variation of accessory minerals with depth.

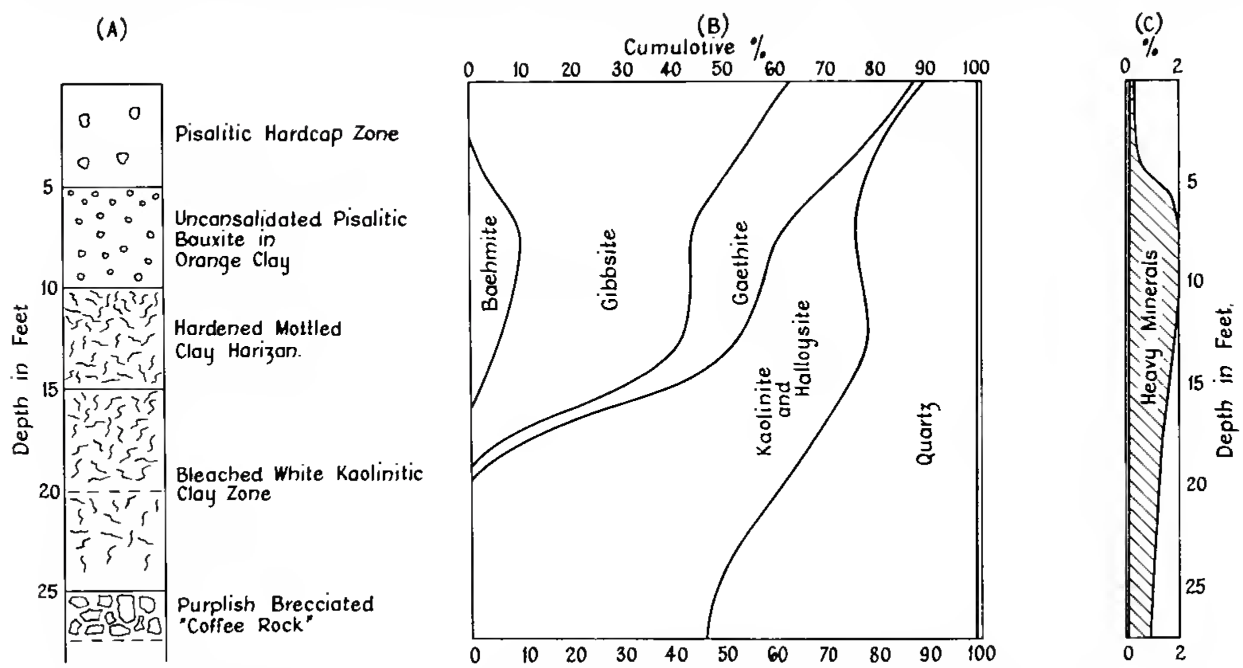

Figure 3.—Mineralogical variation with depth in the Angus Cut profile. (A) Lithological nature of profile, (B) Cumulative percentage by weight of the main mineral components, (C) Exaggerated diagram illustrating variation of accessory minerals with depth.

Field Relations

As part of an investigation into some of the compositional features of Australian bauxites, two bauxitic laterite profiles in the Cobiac Pit and main Jarrahdale opencut were examined and sampled near Jarrahdale, which is situated about 30 miles southeast of Perth. A third more siliceous type was also investigated at Angus Cut near Greenbushes, which is located about 100 miles south of Jarrahdale.

Although in field section all three profiles constitute a surface hardcap zone overlying an earthy pisolitic bauxite horizon (Figs. 1, 2 & 3), the Angus Cut profile unlike that at Jarrahdale shows an intermediate hardened mottled zone between the bleached kaolinite and earthy bauxite horizons.

The hardcap (or duricrust) is typical of that occurring over most of the continent, being pisolitic, generally ferruginous, and possessing an abundance of cavities lined by pale yellowish gibbsitic material (Figs. 4 & 5). Although for the most part irregular in shape, these sometimes (as at Gove, N.T.) form prominent pipe-like structures extending throughout the laterite profile and apparently being derived by the root action (Fig. 6).

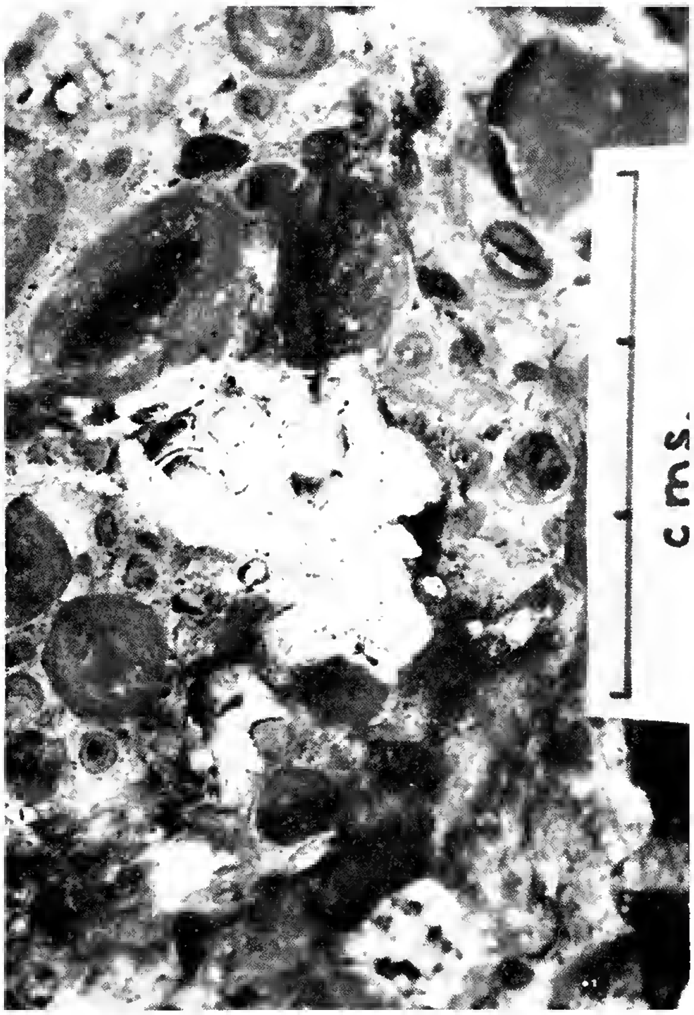

Figure 4.—Initial stages of recrystallisation and cavity formation in the hardcap at Jarrahdale.

Figure 5.—Secondary cavity formation in Jarrahdale hardcap partially filled with fine gibbsitic oolites. These may subsequently be recemented by a compact boehmitic matrix.

Mineralogy

The essential mineral assemblages of the Western Australian laterites are gibbsite, boehmite, kaolinite, goethite, maghemite, metahalloysite, illite, hematite, and variable quantities of amorphous gel material.

Quantitative analyses

Accurate quantitative mineralogical analyses of bauxites are still extremely difficult to obtain even by the various techniques employed here. These complications are particularly evident in samples possessing the highest amorphous gel content. In view of this, frequent discrepancies exist in estimates derived by X-ray diffraction and chemical means. To remedy this, resort was also made to infrared, thermogravimetric, and differential thermal analysis techniques. However, the combined results obtained are still not entirely satisfactory being probably within the order of $\pm$ 10%. These results, obtained for composite samples are summarised in Figures 1, 2 & 3. They show a progressive increase in the ratios of gibbsite to kaolinite and of goethite to quartz with increasing height in each profile. The distribution of boehmite, on the other hand, although showing a corresponding increase in the Cobiac and Angus Cut profiles differs in the Jarrahdale open cut where it is confined to the uppermost 2 feet of the profile.

TABLE 1

Heavy mineral analyses of the lateritic bauxite from the Darling Ranges

	Jarrahdale Opencut	Cobiac Pit	Angus' Cut
Tourmaline	X		X
Zircon	X	X	X
Zoisite	X	X	X
Leucoxene	X	X	X
Scheelite	X	X	X
Pyrite	X	X	
Topaz	X	X	
Hematite	X		
Ilmenite	X	X	
Rutile	X		
Anatase		X	
Garnet		X	
Andalusite		X	X
Cassiterite			X

X = mineral species present.

The heavy mineral constituents of these laterites (see Table 1) although quantitatively low in total per cent, nevertheless show an interesting distribution. In all three profiles they show a progressive increase with height from the basal pallid clay horizon reaching a maximum in the earthy pisolitic horizon, but thereafter decreasing sharply into the overlying

pisolitic hardcap. Quantitative delineations of the total heavy mineral content in composite samples at successive levels in each laterite profile were obtained by digestion of weighed bulk samples in warm sulphuric acid followed by centrifugation to obtain the insoluble heavy fractions. Owing to the small residue weights obtained, however, individual grain counts were not practical but it is significant that in the Angus Cut section, tourmaline forms about 80 to 90% of the overall concentrate being derived directly from the underlying parent granite. For this reason it is considered the mineral fractions obtained are definitely of residual origin and that very little adventitious material exists.

Optical mineralogy

Pisolitic hardcap.—Basically, this horizon is similar in all three profiles being constituted of complexly zoned pisolites ranging from one eighth to several inches in diameter. Among these the smallest pisolites are generally the most complexly zoned and possess dark maghemite-rich cores, but the larger pisolites possess relatively fewer and broader zones enclosing cores of bauxitised parent rock (Figs. 7 & 8). As the proportion of smaller zoned pisolites tends to increase with height in each profile, it is evident that there has been a progressive physical breakup of the parent rock during bauxitisation accompanied by increased zoning of the finer fragmented particles within the horizon of maximum water table fluctuation.

Further studies of the zoning of individual pisolites by chemical and x-ray diffraction means show that apart from a regular variation in iron content, no consistent chemical or mineralogical variation exists between the thin alternating pale yellow and reddish pisolite zones, although the yellowish outer zones generally (as at Weipa, Qld.), are more kaolinite- and boehmite-rich. In addition, whereas the pisolite cores are generally more coarsely crystalline compared with the pale margins and intertitial matrix, they are by contrast predominantly gibbsitic with little or no boehmite. Frequently, however, particularly in the surface levels of the hardcap, the pisolite cores are completely replaced by maghemite with accessory amounts of goethite and magnetite (plus hematite instead of magnetite at Angus Cut). Thus, as opposed to the views of Hagg (1935), Basta (1957) and Takenchi and Nambu (1958), it appears that the maghemite was essentially derived through the dehydration of goethite, although the reducing action of organic matter may also have played a contributory role. Furthermore its close association with magnetite in these pisolites is not unexpected in view of their solid solution relationship (Basta 1959).

Figure 6.—Pipe-structures in hardcap zone of the Cobiac Pit profile.

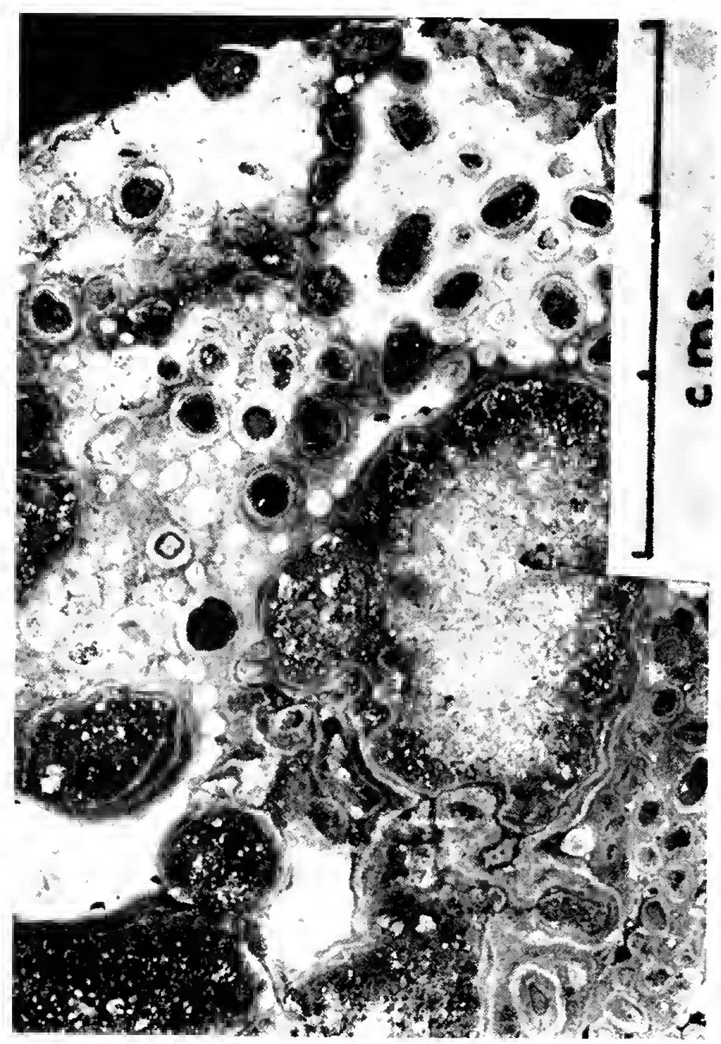

Figure 7.—Pisolitic hardcap from Jarrahdale showing complex zoning of pisolites with frequent maghemite cores.

Figure 8.—Incipient zoning of bauxitised granitic fragment near the bottom of the Jarrahdale profile.

Other products of dehydration in the hardcap zones of these three profiles appear as scattered pale yellow porous patches, which stand out in marked contrast to the predominantly dark red colour of the bauxite. Here again it is possible to observe a complete sequence of change starting from the dehydration and recrystallisation of the reddish pisolites and/or matrix to coarsely crystalline gibbsite and quartz (Fig. 4), until in the final stages irregular cavities partially filled with gibbsite oolites are formed (Fig. 5). Occasionally, however, these oolites are recemented by a yellowish boehmitic matrix and the resulting cavities completely refilled. Similar occurrences of boehmite are also occasionally found at Gove, N.T.

Electron microscopy

Two clay fractions from the Jarrahdale area were examined under the electron microscope. One represented the —200 (B.S.S.) mesh fraction from the 10 to 14 feet section of the Cobiac profile (Fig.1), while the other constituted the gritty white clay immediately underlying the unconsolidated bauxite in the Jarrahdale open-cut (Fig.2).

The first sample from the Cobiac Pit consisted predominantly of hexagonal kaolinite crystals together with a little halloysite, these tubular crystals, as in Figure 9, being now partially uncurled due to dehydration. The sample was thoroughly dispersed in distilled water prior to grid preparation, but even so only trace amounts of gibbsite could be detected by electron diffraction, most of this being very fine and attached to larger kaolinite crystals. It seems probable therefore that the gibbsite crystals being larger and more equidimensional may

Figure 9.—Electron micrograph of white basal clay at Jarrahdale, showing kaolinite crystals, metahalloysite tubular crystals, and particles of amorphous gel. x 30,000.

have sedimented more rapidly in suspension than the platy kaolinite, gel particles, halloysite, fine boehmite, and goethite crystals. Other components of the clay suspension constituted irregular particles, which being non-diffracting are considered to be amorphous gel material although from infrared spectra these appear to be largely boehmitic. Boehmite crystals from aggregate diffraction patterns, however, are largely prism-shaped but are too small to yield individual diffraction patterns.

Examination of the second or white basal clay fraction from Jarrahdale showed this to be constituted essentially of partially uncurled halloysite tubules together with some kaolinite platelets, and again a small amount of amorphous gel material (Fig. 9). Infrared absorption analyses of the latter show this to be composed of equal parts of gibbsite and boehmite.

A final point concerns the nature of iron-bearing components in both the Western Australian and Malayan bauxites. Although in the highly ferruginous hardcap zones both goethite and maghemite are clearly discernible by both x-ray diffraction and using reflected light microscopy, the iron-bearing minerals in ores containing less than 10% Fe_2O_3 are characteristically poorly crystalline with resulting poor diffraction peaks comparable with boehmite.

Examinations of these ores by electron microscopy and electron diffraction have revealed that goethite and not hematite is the predominant iron-bearing mineral present, this occurring as minute often irregular specks attached to larger crystal aggregates—and particularly to the dark amorphous gel particles. Much of the ferruginous component in bauxites could occur in an essentially gel-like form but owing to its poor infrared absorption bands and thermogravimetric characteristics, which are identical with gibbsite and goethite, this is extremely difficult to examine in any detail. It is interesting however that experimental ageing of iron oxide gels at varying pH's by MacKenzie and Meldau (1959) produced only extremely fine goethite microlites in a predominantly amorphous gel, thus substantiating the writer's view that the chief iron-bearing mineral present is goethite and not hematite.

Infrared absorption spectra

As in the southeast Johore bauxites (Grubb 1965) comparisons of absorption spectra show a marked tendency for boehmite to be concentrated in the clayey matrix fractions, whereas gibbsite predominates in the harder concretions and pisolites. Again this emphasises the extremely fine nature of boehmite in these and many other bauxites.

Also of interest here is the detection of some opaline silica in the clay fractions.

Chemical Analyses

Chemical analyses of composite unscreened samples and some finer clay fractions from these were obtained gravimetrically using the tri-acid method, the alumina percentage being taken as the difference between the total R_2O_3 and the Fe_2O_3 obtained by separate titration. The results of these analyses are listed in Table 2.

The distribution of trace elements was investigated in several bauxite samples, and revealed the presence of calcium, chromium, gold, magnesium, sodium, tantalum, thorium, tin and vanadium.

Discussion

From the data presented it is evident that differences exist between the high level laterites (as exemplified by the Cobiac and Jarrahdale profiles) and the lower level Angus Cut section. The most significant of these is the higher grade and greater depth of bauxite ore in the two higher level members. In addition assuming the cumulative increase in heavy mineral content with height in these laterites to be a rough

TABLE 2

Chemical analyses of lateritic bauxite and clay from Angus, Cobiac and Jarrahdale laterite profiles of Western Australia

	Cobiac							Jarrahdale			Angus Cut		
	1	2	3	4	5	6	7	8	9	10	11	12	13
Loss on ignition	32.11	31.25	30.34	30.82	30.59	27.00	26.10	18.40	27.40	8.66	21.44	15.18	12.40
SiO_2	5.42	4.47	7.58	6.38	6.00	9.42	8.87	6.17	5.82	69.04	18.20	29.35	46.41
Fe_2O_3	4.90	10.25	6.18	6.40	11.20	9.48	11.96	26.80	14.00	0.48	11.42	13.52	0.20
TiO_2	0.20	0.70	0.60	1.20	0.29	0.20	0.20	0.80	1.00	0.10	0.75	1.16	nil
Al_2O_3	57.37	53.33	55.30	55.20	51.92	53.90	52.87	47.00	49.50	24.32	46.98	40.80	38.21
Insoluble residue	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	nil	n.d.	2.78

1. 0 – 4′ hardcap horizon from Cobiac profile.
2. 4′— 7′ unconsolidated earthy bauxite section from Cobiac profile.
3. 7′—10′ unconsolidated earthy bauxite section from Cobiac profile.
4. 10′—14′ unconsolidated earthy bauxite section from Cobiac profile.
5. –200 mesh (B.S.S.) " clay " fraction from the 4′—7′ earthy bauxite section. Cobiac profile.
6. –200 mesh (B.S.S.) " clay " fraction from the 7′—10′ earthy bauxite section, Cobiac profile.
7. —200 mesh (B.S.S.) " clay " fraction from the 10′—14′ earthy bauxite section. Cobiac profile.
8. Ferruginous hardcap horizon. Jarrahdale profile.
9. Unconsolidated earthy bauxite horizon, Jarrahdale profile.
10. Gritty white basal clay. Jarrahdale profile.
11. Hardcap horizon. Angus Cut profile.
12. Unconsolidated earthy bauxite. Angus Cut profile.
13. Gritty white basal clay. Angus Cut profile.

Analysts: P. L. C. Grubb and N. Philip.

index of the proportion of material the parent rock during lateritisation, it is evident from Figures 1, 2 and 3 that the proportional increase of heavy minerals with height in the high level Jarrahdale and Cobiac profiles has been far greater than in the lower level Angus Cut section. On the basis therefore that lateritisation occurred here during a single epoch (David 1950) it can be concluded that this was more intensive at higher elevations where tectonic uplift was sufficient to maintain the more rapid percolation of meteoric solutions with dissolved silica. However although tectonic uplift is apparently essential for more prolonged and intensive lateritisation, a critical balance exists, for should this uplift be too rapid the region would be denuded of its surface bauxite horizon through erosion, the ratio of surface run-off to percolating meteoric water increased, and finally the rate of percolation would be too rapid to permit maximum solution of silica and iron from the parent rock. On the other hand if tectonic uplift was too slow the rate of meteoric water percolation would be decreased and because of the resulting high water table level either surface rekaolinisation would occur or in the case of a strongly seasonal climate a hard surface duricrust could form, which would impose an effective barrier to further bauxitisation. These optimum conditions must evidently have been met during the epeierogenic uplift of the Darling Ranges although conditions appear to have been less favourable in the Greenbushes area.

Among the remaining factors influencing the intensive lateritisation within the Darling Ranges belt were its proximity to the sea with relatively high precipitation thus supporting a relatively dense tall forested vegetation which produced a high ratio of meteoric water percolation to surface run-off. Moreover as apparent at Gove, N.T. it is also probable that the total extraction of silica by vegetation constitutes a significant factor in lateritisation. Parent rock has also played a noteworthy role in the Darling Ranges, although as shown also by Loughnan and Bayliss (1961) the overall composition is of little importance. Instead its susceptibility to bauxitisation is determined by several interrelated factors. The chief of these are texture and structure, for while the rock must be relatively fine grained, so as to present the maximum intercrystalline surface area for solution, it must also retain sufficient rigidity during lateritisation so that the percolation rate of meteoric solutions continue unaltered. A third factor is the interrelated mineral and chemical composition for although under otherwise ideal conditions bauxitisation may attack almost any rock type, it is evident that certain mineral assemblages are more readily attacked than others. The explanation of this is not entirely understood but for several reasons appears to be physicochemical with little dependence on overall chemical composition. In the Darling Ranges, the predominant medium to coarse grained granitic rock types clearly meet the majority of these requirements, although the coarser texture of the Angus Cut granite parent rock would explain the more siliceous composition of the resulting bauxite.

The differential segregation of boehmite and gibbsite in these profiles follows closely on similar observations made at Gove, N.T. and in Gippsland, Victoria. Thus, as described earlier (Grubb 1965) it is considered that boehmite constitutes one of the earliest bauxitisation products and that this is progressively replaced by gibbsite during the progressive fall in the water table level. It is interesting to note here that boehmite has been detected as the primary aluminium hydrate after artificial leaching of albite in water under various partial pressures of CO_2 (Lagache 1965). The occasional increases in boehmite content in the uppermost two or three feet of the profile, on the other hand, may be accounted for both by increased desiccation and aeration. Besides, with a relatively thick vegetational cover, the meteoric water near the surface would contain a comparatively high proportion of humic acids and dissolved CO_2, and this would play a dual role. Firstly, as shown experimentally by Keith (1959), the transformation of boehmite to gibbsite can be arrested by saturation with CO_2. Secondly, Sechrist (1963) has demonstrated that the presence of excess CO_2 may increase the surface evaporation rate by 30% and this is quite independent of other factors. However, the retention of only a small proportion of boehmite in the uppermost 2 feet of the Jarrahdale opencut profile is not fully understood but suggests a stationary water table level for a prolonged period with the replacement of boehmite by gibbsite going almost to completion except in the surface horizons where the vegetational cover may have been less dense.

Some comparisons with other Australian bauxite deposits

As already indicated, of the deposits already familiar to the writer those situated at Gove (N.T.) bear the closest resemblance to the Darling Ranges bauxite. In their field relations, although several divergencies exist, all three sections described here from the Darling Ranges are almost identical in lithological succession to the true residual sections situated a mile inland from the coastline of the Gove Peninsula. The chief differences apart from the chemical and mineral composition are that the Darling Ranges laterite possesses a prominent hardcap horizon and appears to have been slightly more eroded. It is uncertain as yet however whether any recemented colluvial horizons, as are common at Gove, occur in the Darling Ranges, none having so far been observed by the writer.

In boehmite content the Darling Ranges are closer to the Weipa deposits than those of Gove, but lithologically they appear to be somewhat different.

No similarity apart from their relatively high monohydrate content exists between the Gippsland deposits and those of the Darling Ranges. This is not unexpected however in view of the former being derived from a basaltic parent rock, having experienced a different tectonic history, and being now buried under carbonaceous clay horizons and Tertiary sands.

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